GRAZING SYSTEMS AND MANAGEMENT STRATEGIES FOR LACTATING HOLSTEIN COWS IN FLORIDA

By

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KEY TO ABBREVIATIONS

ADF – acid detergent fiber
ADG – average daily gain
BCS – body condition score
BG – Tifton 85 bermudagrass
bST – bovine somatotropin
BW – body weight
CP – crude protein
DE – digestible energy
DM – dry matter
DMI – dry matter intake
FCM – fat corrected milk
FI – forage intake
GT – grazing time
HA – herbage allowance
HM – herbage mass
IB – intake per bite
IGF-1 – insulin-like growth factor 1
IVDMD – in vitro dry matter digestibility
IVOMD – in vitro organic matter digestibility
ME – metabolizable energy
MUN – milk urea nitrogen
MY – milk yield
N – nitrogen
NAN – non-ammonia nitrogen
NDF – neutral detergent fiber
NE_L – net energy of lactation
NEFA – non-esterified fatty acid
NRC – National Research Council
NSC – non-structural carbohydrate
OM – organic matter
OMI – organic matter intake
PUN – plasma urea nitrogen
RB – rate of biting
RP – Florigraze rhizoma peanut
SCC – somatic cell count
SR – stocking rate
SUP – supplementation rate
THI – temperature-humidity index
TMR – totally mixed ration
TT – temperature transponder

Abstract of Dissertation Presented to the Graduate School
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Two experiments tested effects of two pasture forage species, the legume rhizoma peanut (RP; *Arachis glabrata*) or bermudagrass (BG; *Cynodon spp*. cv. 'Tifton 85'), two supplementation rates (SUP; 0.33 or 0.5 kg/kg of milk), and two stocking rates (SR) on performance of mid-lactation Holstein cows.

The RP supported more milk per cow (17.3 vs. 16.3 kg/d), but less milk per hectare than BG pastures. With each additional kg of supplement fed above the low SUP, cows produced an additional 0.87 kg of milk/d if grazing BG vs. an additional 0.43 kg of milk/d if grazing RP.

Respiration rates and body weight (BW) losses generally were greater when treatments stimulated milk production. Optimum SR for BG and RP pastures were approximately 10 and 5 cows/ha. Cows grazing RP had greater forage (11.3 vs. 7.6 kg/d;

2.26 vs. 1.52% of BW) and total (17.7 vs. 13.5 kg/d; 3.54 vs. 2.70% of BW) organic matter intakes (OMI). Increased supplement provision increased daily OMI, but decreased forage intake. Substitution of forage with supplement (kg/kg) was 0.51 for RP and 0.18 for BG.

A third experiment tested the effects of housing pasture-based cows in barns or on pasture from 0800 to 1530 h. Within housing treatments, cows did or did not receive bST. A fifth treatment tested the effect of feeding silage to barn-housed cows injected with bST.

Intake of pasture and milk production were similar for both housing managements although cows housed in barns spent less time grazing. Treatment with bST increased milk production (18.1 vs. 16.6 kg/d). Production was unaffected by silage intake.

Housed cows and bST-treated cows maintained or gained BW. Respiration rates and body temperatures were greater for pastured cows, and body temperatures were greater in cows given bST.

Improved grasses in combination with large amounts of supplemental feeds are likely most suited for pasture-based dairy production systems in Florida. Providing fans and sprinklers to relieve heat stress and injecting with bST was only moderately effective to stimulate milk production of midlactation cows in a pasture-based system.

CHAPTER 1
INTRODUCTION

While use of pasture-based production systems is the norm for beef production in the U.S., pasture use for dairy production was all but abandoned until the mid- to late 1980s when management of pastures using intensive rotational stocking began to be adopted. During a time of financial duress, pasture systems garnered renewed interest, primarily due to perceptions that they have reduced production costs, require less initial investment, have less demanding labor requirements, and are more environmentally sound than production with confined-housing.

Information regarding their use is limited, however, particularly for producers in the Southeast. Regardless of the production system, producers in the Southeast must overcome several challenges to be successful. The lesser quality of perennial forages adapted to the region and the negative effects of high heat and humidity on animal performance are the primary limitations to production. Thus, information in this arena is vital because the challenges to production likely are more formidable for pasture-based dairies.

Forages adapted to the region typically are of less quality than cool-season species due to greater concentrations of fiber and lower concentrations of digestible nutrients. Other potential limitations of pasture-based systems include variability in forage supply and nutritive value, both of which are highly dependent upon climatological conditions.

Pasture-based production systems are energetically demanding of the animal. Cows face greater energy requirements for walking and foraging in addition to energy demands for dissipation of heat load during periods of high ambient temperature and high humidity. Such requirements may limit severely the nutrients available for production.

Production potential of pasture-based dairies may also be affected by numerous management practices. Issues of particular concern include suitability of available forage species, types and amounts of supplement to feed, appropriate stocking rates, effects of management strategies upon animal production and physiology, and the interactions of these factors.

The studies described herein were conducted to test the effects of forage species, supplementation rate, stocking rate, and some potential management practices on animal intake and performance. Some simple estimates of income are also reported along with concluding statements regarding the viability of such systems.

CHAPTER 2
LITERATURE REVIEW

Since the 1980s, the economics of dairying in the United States has put farmers in a severe cost-price squeeze (Muller et al., 1995). Reducing feed costs has become critical because these costs are estimated to account for 50 to 60% of operating costs (Elbehri and Ford, 1995). To cope with this economic reality, many dairies using confined housing have increased herd size. Technological advances have helped drive this change (Lanyon, 1995), and typically are most profitable when employed on a large scale (Thomas et al., 1994). Increasing herd size can help farmers reduce feed costs per cow by increasing purchasing power with larger commodity purchases (Lanyon, 1995). Further, fixed costs can be reduced by increased use of farm equipment and greater throughput of cows through the milking parlor. These management changes rely upon increased efficiencies and greater milk production to increase profit but both "increased herd size and increased technological sophistication have resulted in dairy production becoming an even more capital-intensive agribusiness" (Thomas et al., 1994, p. 1).

Facing the same economic and environmental pressures as other dairies but without the ability or desire to expand the size of their herd and facilities, some producers have opted for another way to improve profitability. Their strategy relies on reduced levels of inputs and lower cost structures (Parker et al., 1993). This is attempted by use of alternative forage feeding systems, particularly, intensive grazing (Elbehri and Ford, 1995). "Smaller farms have been subjected to greater financial stress than properties

supporting large herds" (Parker et al., 1992, p. 2587, citing Hallberg and Partenhiemer, 1991, and citing Kaffka, 1987), thus it is understandable that "most interest in grazing systems has been shown by dairy producers with herds of fewer than 100 cows" (Parker et al., 1992, p. 2587).

Milk production per cow or farm may decrease in grazing herds as producers change from management of confined housing to management of grazing systems, but graziers assume that the decrease in production costs is greater than the cost of lost milk production, thus garnering greater net profit. Some studies (Emmick and Toomer, 1991; Parker et al., 1992) have indicated returns per cow can increase from $85 to $165 with the use of pasture (Muller and Holden, 1994). Other reasons cited for choosing pasture-based production systems include reduced labor, best land use, improved cow health, and reduced manure handling, as well as improved quality of lifestyle for the owner/manager (Loeffler et al., 1996). One survey indicated that total hours of labor were not decreased in grazing-based systems, but that time devoted to various tasks changed as that activity's importance in the system changed (Loeffler et al., 1996).

Climatic Challenges to southeastern Dairies

Regardless of the production system, the climate of the Southeast presents unique challenges for producers in the region. Of particular concern is the effect of heat and humidity on both plants and livestock. The effect of the climate may be more adverse for animals on pasture.

Climatic Effects on Forages

The perennial, warm-season forages adapted to the Southeast are typically of lower nutritive value than either cool-season perennials or warm-season annuals

[National Research Council (NRC), 1989]. Even at similar NDF and lignin concentrations, warm-season grasses are less digestible than cool-season grasses (Barton et al., 1976; Mertens and Lofton, 1980). Minson and McLeod (1970) reported that the mean DM digestibility coefficient for tropical grasses was 13 percentage units less than that of temperate grasses. When grown at warmer temperatures, forages have greater concentrations of fiber and are less digestible than those grown under more temperate conditions (Deinum and Dirven, 1976; Fales, 1986). Greater humidity also creates potential for additional plant stresses via increased phytopathogen load.

For southeastern producers using confined-housing systems, growing high quality forages may be of limited concern. Despite the climatological challenges, acceptable quality maize (*Zea mays* L.) silage can be grown locally and high quality alfalfa (*Medicago sativa* L.) hay is available for purchase from growers in western states. Moreover, producers in the region using confined-housing frequently use by-product feeds such as brewer's and distiller's grains, whole cottonseed, and cottonseed hulls. These feeds may supply substantial portions of the diet's roughage, potentially reducing the need for homegrown forages.

The ability to grow superior quality forages is of particular concern for graziers (producers using grazing systems). Perennial, warm-season forages typically are of lower quality than cool-season forages as measured by comparisons of animal performance (Galloway et al., 1993b). Stobbs (1976, cited by Ruiz, 1983) showed that Jersey cows grazing immature tropical pastures produced approximately 60% as much milk as those grazing temperate pastures. Cool season species generally are considered to be of greater quality due to greater digestibility because of differences in the relative

amount and arrangement of tissues (Akin, 1986a,b, p. 194). However, warm-season species do have the agronomic advantage of being adapted to the region. Thus, despite their lower quality, forages such as bahiagrass (*Paspalum notatum*) and bermudagrass (*Cynodon dactylon* (L.) Pers.) are the foundation of forage production systems for grazing animals in the Southeast.

Other forage quality concerns for graziers may include pasture variability in supply and nutritive value over the course of the growing season (Holt and Conrad, 1983). Changes may correspond with changes in climatic conditions, such as temperature, soil moisture, leaf/stem ratio and the proportions of dead leaves in the sward (Beaty et al., 1982; Henderson and Robinson, 1982). Grazing dairies, reliant upon locally grown perennial forages, thus are likely more susceptible to changing forage quality than many dairy farms using confined housing.

Climatic Effects on Animals

Higher environmental heat and humidity affect dairy cows negatively by limiting their ability to dissipate body heat. In such circumstances, cows are likely to decrease DMI, and in more severe conditions may also suffer from heat-related disorders such as respiratory alkalosis/metabolic acidosis, ketosis related to excessive decrease of DMI, and laminitis associated with feeding diets of large concentrations of grain (Sanchez et al., 1994; Nocek, 1997; Ørskov, 1999). Heat stress also impairs the cow's reproductive performance and embryo survival (Thatcher and Collier, 1986; Wolfenson et al., 1988; Ealy et al., 1993).

Heat stress can be mitigated with cooling technologies. The technological advances in confined-housing systems include well-ventilated barns with high roofs and

high-speed fans with wetting mechanisms (Flamenbaum et al., 1986; Chen et al., 1993; Chan et al., 1997). Such facilities increase shade and evaporative cooling, providing relief from excessive ambient temperatures.

Ways to cool cows on pasture are limited, however. Fixed and mobile shade structures, trees, cooling ponds, and strategic movement (e.g. allowing cows access to cooling barns during times of high ambient temperature) represent the major methods used to reduce heat stress of pastured animals. In addition, pastured cows face additional heat stress from the heat of activity caused by grazing and walking to and from the parlor. Thus, the effect of heat stress is likely of greater concern for graziers.

Recent literature regarding grazing dairy systems in the southeastern United States is limited, although results with beef steers on pasture may have application. The majority of data pertaining to dairy cow grazing in North America has been published by researchers working in the Northeast and Midwest under very different environmental conditions. Some research from Australia and other tropical areas may be applicable to the southeastern environment, but the forages grown are typically of different genera and the amounts of concentrate fed are less than the amounts provided by U.S. producers. Thus, while pasture-based dairies may be a viable alternative to confined housing systems in the Southeast, more information on factors affecting their viability is needed.

Energy Considerations for the Grazing Ruminant

Energy requirements for grazing cattle are likely greater than requirements for cattle housed in confinement (Van Es, 1974; NRC, 1989). For lactating cows housed in confinement, the NRC (1989) estimates that the maintenance requirement is 80 kcal of NE_L/kg of BW $^{0.75}$ (Moe et al., 1972) which includes an activity requirement of 10%.

Based on work by Brody (1945), the NRC (1989) recommends an additional allowance of 3%/km walked per day and an added 10% maintenance allowance/d for cows grazing "good pasture." Brody (1945) estimated that standing (vs. lying down) increases energy expenditure by 9%, but research that is more recent suggests this is an underestimate (Clark et al., 1972; Vercoe, 1973). Robbins (1993) suggested that a better estimate of the cost of standing versus lying (including small position changes) would be 20%. This does not mean to suggest that the grazing animal necessarily stands more than an animal in confined housing, but it does emphasize the point that energy needs for grazing ruminants are likely underestimated by some current energy system recommendations.

Depending on the pasture or environmental conditions, the requirements might be expected to be much greater (Osuji, 1974; DiMarco and Aello, 1996; Noller, 1997, cited by Reis, 1998). Noller (1997, cited by Reis, 1998) estimated that increasing the energy requirements by 10 to 20% is probably not enough for cattle grazing tropical forages under tropical conditions. DiMarco and Aello (1996, cited by Reis, 1998) indicated that for grazing cattle, maintenance energy might need to be increased 27 to 30%.

The energy requirements of grazing animals may be expected to increase if animals require more time for foraging, if topography is hilly, or if environmental conditions compromise thermoregulation (Robbins, 1993). Additionally, the efficiency associated with consuming the diet is likely reduced. Osuji (1974) reported that sheep fed fresh grass required approximately 12% more metabolizable energy than those fed an equivalent amount of dry matter as dried grass. The increase was due primarily to the additional time required to achieve equal DMI.

Grazing is energetically expensive for the cow, and "any improvement in performance will hinge upon increasing energy intake or increasing the efficiency with which ingested energy is utilized" (McCollum and Horn, 1990, p. 1). Even with relatively high quality cool-season pastures, animal performance is often less than might be expected given the chemical composition and nutritive value of the forage. This may be due to the lower efficiency of utilization of fresh forage (Osuji, 1974) or to differences in energy intake (Kolver and Muller, 1998). Kolver and Muller (1998) examined the reason behind performance differences of cows consuming high quality pasture and those eating a totally mixed ration (**TMR**) primarily composed of corn and legume silages, high moisture shelled corn, whole cottonseed, soybean meal, legume hay and wheat middlings. The concentration of NE_L of the diets was similar (1.63 and 1.65 Mcal/kg of DM for pasture and TMR), but NE_L intake was less (32.4 vs. 40.2 Mcal/d) for cows grazing pasture. The apparent DM digestibility of the diets was approximately equal (77 and 76% for pasture and TMR, respectively), but dietary NDF and ADF concentrations were 40 and 20% greater for the pasture diets. The authors reported that differences in intake rather than differences in energy between pasture and TMR limited energy intake by pastured cows.

Some Animal and Nutritional Factors Influencing Feed Intake

Understanding the mechanisms regulating feed intake historically has been a key research objective, because the "amount of forage consumed is the major determinant of production by animals fed forage-based diets" (Buxton et al., 1995, p. 10). As much as 60 to 90% of the variation in digestible energy intake may be due to animal variability, with 10 to 40% due to diet digestibility (Crampton et al., 1960; Reid, 1961). Though

intake and digestibility may be strongly correlated (Anderson et al., 1973), intake of digestible nutrients "is affected more by differences in intake than by differences in digestibility" (Waldo, 1986, p. 618).

Much effort has been made to determine whether voluntary intake was limited primarily through physical or physiological control mechanisms. Conrad et al. (1964) examined results from 114 trials with lactating cows and reported the relative importance of physical and physiological factors regulating feed intake changes as diet digestibility increases. Intake of diets having between 50 and approximately 67% digestibility was thought to be limited by physical factors such as digestibility of a feed and its rate of passage through the digestive tract. Intake of diets having a digestibility greater than 67% was limited primarily by physiological control mechanisms. This "breakpoint [67%] is likely a convenient mathematical simplification" (Allen, 1996, p. 3064) because voluntary intake is likely regulated by numerous, integrated signals from the intestinal tract and digestive organs (Forbes, 1996). Regardless of the breakpoint or precise mechanisms of intake control, research supports the theory that intake often is restricted by rumen distention, i.e. physical constraint (Balch and Campling, 1962; Grovum and Phillips, 1978; Friggens et al., 1998).

Constraints on feed intake by physical mechanisms are, in part, a function of digestive tract capacity and are related to energy balance (Allen, 1996). Voluntary DMI of cows in negative or slightly positive energy balance decreased in response to inert fill added to the reticulorumen but was unaffected in cows having greater positive energy balance (Johnson and Combs, 1991, 1992; Dado and Allen, 1995). This is of particular relevance for the grazing dairy cow which has increased maintenance energy

requirements because of increased walking and grazing activities (NRC, 1989). The increased energy requirements of these activities may lower energy balance, putting downward pressure on voluntary DMI.

Some have suggested that intake capacity is in part a function of the energy required for production. For example, increased rumen volume has been attributed to the increased energy demand of lactation (Tulloh et al., 1965), and Redmond (1988, cited by Allen, 1996) reported that weight of reticulorumen contents increased more than 40% in the first 2 months of lactation in dairy cows. In a comparison of rumen load and clearance between lactating and non-lactating sheep, Weston and Cantle (1982) showed that both were increased by lactation.

Goetsch et al. (1991, p. 2635) reviewed 18 Latin-square experiments to "determine effects of various feedstuffs . . . on intake and digestion by Holstein steer calves ingesting bermudagrass hay ad libitum." The authors reported that fiber fractions in the feeds were of negligible importance and the coincident "absence of strong relationships between bermudagrass composition and digestion . . . implies that variation in chemically fractionated fiber components of bermudagrass had little impact on nutrient status and (or) gut fill regulation of DMI" (p. 2639) further noting that growth and energy utilization may have been involved with regulating DMI.

This remains a subject of debate, however. Friggens et al. (1998) fed constraining or non-constraining diets over a lactation, switching the diets of half the dairy cows in each test group at 153 days in milk. Diets were composed of grass silage and a barley-based concentrate. The NDF concentrations of the diets were approximately 37 and 43% and the ADF concentrations were approximately 21 and 26% for the low- and high-fill

diets, respectively. Milk production was greatest from cows initially fed the non-constraining diet, but when switched to a constraining diet, intake declined rapidly "even though, immediately prior to the changeover, cows on [the non-constraining] diet had a much greater milk yield and thus a much greater presumed energy requirement," (p. 2236). The authors concluded that milk "yield had no effect on the capacity of the cow to consume a constraining diet . . . [and] intake capacity is independent of cow performance" (p. 2237). The authors noted that intake capacity might be expected to change during very early and very late phases of lactation as others have shown (Hunter and Siebert, 1986; Stanley et al., 1993).

The results of Friggens et al. (1998) underscore the importance of dietary factors that affect gut fill. Of a forage's intrinsic characteristics, fiber is thought to be the main component limiting voluntary intake due to its "filling properties" (Jung and Allen, 1995). In 1965, Van Soest reported large negative correlation between percent of plant cell wall constituents (NDF) and voluntary intake. Neutral detergent fiber represents the total cell wall fraction of a feedstuff, and is considered a mechanism controlling forage intake by ruminants (Waldo, 1986; Jung and Allen, 1995).

Intake of perennial, warm-season grasses in the Southeast typically is considered limited by physical (fill) effects due to their high fiber concentrations and low digestibilities. The National Research Council recommends dietary NDF concentrations of 25 to 28% in rations for lactating cows (NRC, 1989), but the majority of summer, perennial grasses common to the region generally have concentrations of NDF in excess of 70% (DM basis). If warm-season perennial grasses are the sole forage source in the diet, their large NDF concentrations might represent a steep hurdle for producers trying to

maintain adequate intake for high-producing dairy cows. However, the strength of the negative relationship between fiber and intake (or digestion) for animals consuming bermudagrass has been questioned (Golding et al., 1976a; Jones et al., 1988; Goetsch et al., 1991) and bears further investigation.

Some Non-Nutritional Factors Affecting Behavior and Forage Intake Of Grazing Ruminants

Mechanistic Components of Forage Intake

A mechanistic or mathematical model of forage intake by the grazing ruminant was first put forth by Allden and Whittaker (1970) following the work of Allden (1962). The model reduces forage intake (**FI**; kilograms) to the product of the main components of grazing behavior; that is time spent grazing (**GT**; minutes or hours), rate of biting during grazing (**RB**; bites per minute), and the intake of forage per bite (**IB**; grams). Hence the equation: FI = (IB*RB*GT)/1000.

Research indicates that if herbage mass is maintained above amounts which restrain intake, animals can maintain fairly constant amounts of intake by adjusting IB, RB, and GT (Willoughby, 1959; Allden and Whittaker, 1970). Of these three variables, IB is the most affected by sward conditions (Hodgson, 1985). Intake per bite "normally falls sharply as herbage mass or sward height declines" (Hodgson, 1985, p. 340, citing Allden and Whittaker, 1970 and Hodgson, 1981). Negative correlations between IB and herbage on offer ($r = -0.61$) and sward bulk density ($r = -0.70$) have been shown with tropical pastures (Stobbs, 1973). Sward height may be positively related to intake of warm-season species (Flores et al., 1993), though universality is unlikely when one considers the range in morphologies of tropical forages.

Leaf distribution in the canopy has the greatest influence on IB, (Stobbs, 1973; Hodgson, 1985) because IB is the product of "bite volume (depth x area) and the bulk density (weight per unit volume) of herbage within the sward horizons encompassed in a bite" (Hodgson, 1985, p. 342-343). Other factors that influence IB include sward height, presence of stem and pseudostem horizons, and the height of these horizons relative to total sward height, all of which affect ease of prehension and depth of biting into the canopy (Flores et al., 1993).

Sward maturity has strong effects on efficiency of the grazing activity due to its effect on leaf distribution in the canopy (Stobbs, 1973; 1974a). Stobbs (1973) studied IB in dairy cows grazing tropical swards at 2, 4, 6, or 8 wk of regrowth. The IB was limited by the low yield and density of herbage at 2 wk of age even though pastures contained 82% leaf. Intake per bite increased at 4 wk with increasing available herbage, but decreased with increasing maturity (6 and 8 wk) primarily due to decreasing leaf:stem ratio. Mean IB at 2, 4, 6, and 8 wk were approximately 0.23, 0.27, 0.17, and 0.15 g OM/bite. This research also compared responses between species (*Setaria anceps* and *Chloris gayana*) that showed that sward maturity affected IB differently between species (Stobbs, 1973). Mayne et al. (1997) reported intakes of 0.4 to 1.1 g of DM/bite for cows grazing ryegrass pastures. These values are quite high, but their estimates were made indirectly. Pulido and Leaver (1997) did not report IB but reported rates of intake of perennial ryegrass of 20 to 30 g of OM/min. Assuming a bite rate of 55 bites/min, IB ranged from 0.36 to 0.55 g of OM/bite.

Research into the effect of progressive defoliation on intake of tropical pastures showed that cows selected more than 80% leaf from the upper layers of the sward in the

early stages of defoliation (Chacon and Stobbs, 1976). Work by Roth et al. (1990) showed that cattle continued to select large proportions of leaf even as leaf percentage of the canopy decreased. As the quantity of leaf decreases, animals increased GT, RB, and total number of eating bites, but these activities were not sustained as pastures became severely defoliated (Chacon and Stobbs, 1976). Chacon and Stobbs (1976) suggested that leaf yield would give a better expression of forage on offer than the more commonly used "grazing pressure".

Biting rates between 51 and 63 bites/min were reported by Chacon and Stobbs (1976) when cows grazed warm-season forages. Rates as great as 90 bites/min on temperate pasture were reported by Hodgson (1985) but this likely represents total jaw movements. Rates of biting declined linearly with increasing length of grazing period when forage was not limiting (Stobbs, 1974b). Greenwood and Demment (1988) compared intake behavior of unfasted steers or those fasted for 36 h. They reported that ingestive bites increased approximately 30% (38.9 vs. 29.7 bites/min) due to fasting, but this response was seen during the morning only.

Under forage-limiting conditions with temperate pastures, RB increases as IB decreases, but RB rarely increases enough to maintain herbage intake (Allden and Whittaker, 1970; Hodgson, 1981). Moreover, the changes in RB likely are due to the manipulative jaw movements required to harvest the forage (Stobbs, 1974b; Chambers et al., 1981). With temperate pastures, RB may increase when forage is limited due to a reduction in manipulative jaw movements (Hodgson, 1985), but low availability of herbage would likely decrease ingestive RB with most tropical pastures, as animals would spend more time selecting leaf material.

In a comparison of grazing of cool- and warm-season grasses, Stobbs (1974b) reported that RB was much less with Abyssinian barley (*Hordeum vulgare*) than with *S. anceps*, and the decline in RB over time was less with the tropical grass. Cows grazing barley were observed grasping large mouthfuls of forage with their tongues and chewing the forage several times before swallowing, whereas cows grazing *S. anceps* took small amounts of herbage and their mastication bites accounted for less than 5% of total grazing bites.

A more apparent behavioral response to decreasing IB is an increase in GT, but the degree of this compensatory mechanism is also limited, such that daily FI variations may reflect closely the observed variations in IB (Hodgson, 1985). Stobbs (1974a) reported that cows rarely take more than 36,000 prehension bites in a day. Based on this value and the biting rates reported by Chacon and Stobbs (1976), the upper limit to daily grazing time would be 10 to 12 h, though the latter authors reported 39,600 prehension bites/d in one study, and GT as great as 800 min/d with cattle grazing tropical legumes have been reported (Smith, 1959; Stobbs, 1970). In the study by Chacon and Stobbs (1976), average maximum GT reported was 10.75 h/day, and GT patterns were curvilinear. Cows grazed approximately 9 h during the first few days on a new pasture. Grazing time increased to a maximum between days 3 through 6 then subsequently declined "despite a reduction in the quantity of herbage on offer in the later stages of defoliation" (Chacon and Stobbs, 1976, p. 714).

Work by Pulido and Leaver (1997) has shown that level of performance affects intake. The authors measured intake of cows having initial milk yields of 21 or 35 kg/d.

On average, cows grazed an additional 2.45 min for each additional kg of daily milk produced.

Grazing time also may be dependent upon the system of grazing management utilized. Le Du et al. (1979) reported that with rotational stocking, cows did not compensate for decreased herbage availability with increased GT. Rapid defoliation with strip-grazed pastures would be expected to make large alterations in canopy structure, requiring animals to increase manipulative jaw movements (Hodgson, 1981) in order to consume a large proportion of leaf material.

Daylight and Temperature

In general, cows graze primarily during daylight hours, exhibiting strong periodicity in grazing behavior (Hughes and Reid, 1951; Stobbs, 1970). Adams (1985) noted that most grazing behavior studies show that cows typically have a major grazing period occurring early in the morning and one later in the afternoon. Additional intermittent grazing bouts occur throughout other periods of the day and night.

Phillips (1989) reported marked reluctance of cattle to eat at night (Phillips and Denne, 1988) even in hot climates (Alhassan and Kabuga, 1988), but this may be true more for steers than for lactating animals which likely are under greater heat strain. Stobbs (1970, p. 242) reported that "during the night cows grazing tropical pastures behave more as individuals" and that "high yielding cows can spend a considerable length of time grazing during this period." While Stobbs (1970) indicated that night grazing might be limited to 30% of grazing time, work by Seath and Miller (1947) indicated that in hot, humid environments (Louisiana), cows would graze more during night time. Part of the differences in these studies may be in the designation of night,

however, and Stobbs (1970) noted that greater than 50% of grazing would often occur between a.m. and p.m. milkings which occurred after dawn and before dusk, respectively.

Measurement of Forage Intake in Grazing Ruminants

Several methods of intake estimation for animals on pasture have been explored. Each method employs different assumptions which must be met if the estimates are to be valid (Moore, 1996).

Early attempts to estimate intake from individual animals included use of fecal collection bags for total fecal collection. In addition to the potential for loss or urine contamination due to poor design or lack of fit, the bags also have the potential to stress the animal and to alter intake by changing grazing behavior.

To avoid such problems, other researchers cut and carried green pasture to animals kept in confinement. Though this approach affords a great degree of precision, it may be highly inaccurate because it reduces both the opportunity for selection and the work required to harvest the forage. Experimental results are likely most affected when swards are highly heterogeneous or when environmental factors or sward density would have large effects on grazing behavior.

Marker technologies for the estimate of FI of grazing animals have been used extensively. Markers are reference compounds used to investigate both chemical (hydrolysis and synthesis) and physical (flow) digestive processes (Owens and Hanson, 1992). Fecal output (flow) is the measure of interest in the grazing animal because it can be used to calculate intake using the following equation: FI (kg) = Fecal output (kg)/(100 - diet digestibility (%)).

Characteristics of an ideal marker were outlined by Owens and Hanson (1992) and include the following traits: 1) it should be unabsorbable, 2) it should not affect or be affected by animal or microbial digestive processes, 3) its flow should closely mimic that of the material it marks, and 4) it must be analyzable with a specific and sensitive methodology. No single marker currently meets all these criteria.

Both internal (a dietary fraction such as lignin or plant alkanes) and external (e.g., colored plastic chips or rare earth metals) markers have been employed. Use of either type of marker relies upon an accurate estimate of its intake. This is controlled by the researcher using external markers, but calculation of internal marker intake depends upon accurate estimates of what the animal consumes. This may be a particular problem in grazing situations where herbage consumed may not be the same as selected by the researcher.

The external marker, Cr_2O_3, has been used extensively but its suitability has been questioned (Ellis et al., 1980). The Cr_2O_3 does not associate with a particular liquid or feed fraction and thus may settle out of the rumen contents and flow with large variability, particularly when animals consume forage diets. Holden et al. (1995, p. 158) worked with Cr_2O_3 and noted that significant "daily variation in DMI indicates that analysis of composited samples of forages and feces for intake determination may not be adequate for estimation of intake under grazing conditions." Another disadvantage of using Cr_2O_3 is the multiple doses required over several days in order for Cr to reach equilibrium concentrations in the digestive tract. Additional handling of animals is undesirable, particularly when it has potential to disturb established patterns of grazing behavior

More recently, use of pulse-dosed markers has gained acceptance. Animals are dosed once with labeled feed fractions, and numerous fecal samples are collected over a period of time long enough for the label source to have cleared the animal (typically 96 or more hours). A nonlinear equation relating time after dosing to fecal [Cr] is used to generate parameters for the estimation of fecal output (Pond et al., 1987). This method has advantages in that the animals observed need only be handled once for dosing.

Fiber mordants, especially Cr-mordanted fiber, have been used as markers due to the tenacity with which heavy metals bind the fiber particles. Disadvantages to this method include the amount of effort involved in preparing mordanted fiber and the potential negative effects of mordanting upon passage characteristics of the fiber particles (Ellis et al., 1980).

Estimation of intake using external markers also requires an accurate estimate of diet digestibility. Pasture samples may be obtained with surgically altered animals (esophogeally- or ruminally-fistulated) or by hand plucking. Estimates of diet digestibility are then obtained with in vitro techniques. Either method can be inaccurate because potential exists for the sampling animal or for the researcher to select plant material that is different from the plant material chosen by the animals being studied. If supplements are fed, they may further alter diet digestibility, thwarting accuracy of estimation.

With each of these methods, care must be taken during the laboratory analysis, since feces must go through several preparation steps prior to the Cr analysis. An additional difficulty with marker methodologies is the large number of samples which must be collected and processed to make reasonable estimates of intake.

Herbage intake for individual animals also can be estimated with measurements of grazing behavior, where FI = GT*RB*IB. This method may be beneficial in overcoming any effects that supplemental feeds may have on estimates of diet digestibility. However, all three measures for the estimate are quite variable over time, especially with changes in sward conditions (Stobbs, 1973; Chacon and Stobbs, 1976; Hodgson, 1985). Further, it is unlikely that a researcher would have access to more than a few esophogeally-fistulated animals, limiting the number of estimates of IB, and the fistulated animals may not be representative of the population of interest.

Another common method of estimating intake is by disappearance of herbage mass (**HM**). On rotationally stocked pastures with short (1 to 3 d) grazing periods, HM is estimated both pre- and post-graze with devices such as sward sticks, rising plate meters or capacitance meters that allow rapid collection of numerous measurements. The difference between pre- and post-graze HM (disappearance) is the herbage assumed eaten by the grazing animal(s). Such estimates are more suitable when measuring group intakes and are advantageous with respect to eliminating effects of supplement on forage digestibility (Milne et al., 1981). However, their usefulness is limited to conditions where pastures are uniform.

Herbage Allowance or Stocking Rate Effects on Forage Intake and Performance of Ruminants

Due to the complexity of plant-animal interactions and the difficulty of obtaining such information, most research regarding these relationships considers only the gross effects of herbage allowance (**HA**; kg of forage DM/kg of animal live weight), grazing pressure, or stocking rate (**SR**) on animal performance. Several models have been proposed to describe these effects (Mott, 1960; Jones and Sandland, 1974; Mott and

Moore, 1985). In all the models, as SR increases, animal gain decreases but gain per land area increases. A variant model by Jones (1981) suggested that at very low SR, gain/animal also might be compromised, and Stuth et al. (1981) reported that at high amounts of daily HA of bermudagrass pastures, defoliation efficiency is reduced.

Much of the debate among researchers appears to center on the nature of the animal responses at the extremes of HA. Hart (1972) stated that animal gain decreases linearly in response to increasing SR (animals/land area), and thus gain to land area is necessarily curvilinear. Matches and Mott (1975, p. 205) noted that "the exact form of trends reported in the literature have differences depending on the researcher and circumstances of experimentation." The rapid declines in output (per animal or land area) proposed by Mott (1960) are likely most applicable to limited-input, extensive grazing systems (Pearson and Ison, 1997) unsuited for intensive milk production.

Contention also has arisen over the nature of DMI in response to HA. Hodgson (1975, cited by Stockdale, 1985) reported that intake followed HA in a linear fashion. Others have reported asymptotic intake responses to HA (Allden and Whittaker, 1970; Stuth et al., 1981). Stockdale (1985) reviewed eight experiments under Australian conditions and noted that though DMI of grazing dairy cows was reduced with decreasing HA, the relationship was not always curvilinear. He noted that combining the data from all the experiments resulted in a significant quadratic term. The intake response to increasing HA reported by Le Du et al. (1979) was positive and asymptotic and similar responses were reported in a review by Phillips (1989). However, the nature of the response likely is linear over the range of SR typically used (Jones and Sandland, 1974).

As HA increases, forage intake increases, primarily due to increased opportunities for diet selection (Le Du et al., 1979). Thus the nutritive value of forage consumed also increases, though nutritive value of the total sward may decrease due to accumulation of senescing or senescent leaves and stems (Hamilton et al., 1973; Hodgson, 1985).

Piaggio and Prates (1997) noted good correlation between steer gains and HA within season on range pastures. The nature of the response was quadratic, but a regression equation explaining the relationships between intake and HA or between gain and HA over an entire year could not be fitted. Thus, the authors created a new variable, corrected energy pressure. The product of HA and metabolizable energy (**ME**) of herbage, corrected energy pressure was scaled for availability and possibility of selection which was simplified to the proportion of green material in the sward. The relationships between intake or gain and corrected energy pressure were strong ($R^2 \geq 0.82$) and curvilinear.

Phillips (1989) reviewed studies of lactating cows grazing temperate pastures and producing approximately 15 to 18 kg of milk/d. He reported that to prevent a decline in individual performance, minimum HA should allow for DMI of at least 40 g of OM/kg of liveweight per day. This is in contrast with a value of 60 g of OM/kg of liveweight per day suggested by Minson and Wilson (1994). Studies of cool-season pasture grasses suggest that maximum intake occurs when HA is approximately twice intake (Le Du et al., 1979), but HA required for maximum yield/cow may be greater with tropical pastures (Stobbs, 1977). Cowan and O'Grady (1976) indicated that DMI was depressed due to decreased grazing time when HM was less than 2000 kg/ha in tropical grass-legume pastures.

The response of DMI to HA appears to vary depending upon length of the experiment. Stockdale (1985) reported that average DMI was 2.9 kg/d greater with long-term experiments than short-term experiments, regardless of the HA. The author suggested that greater intake in long-term experiments was due to adaptation.

Stocking rate may have both short and long-term consequences for both pasture and animal production, particularly for forage species that exhibit seasonal growth habits. Intense grazing bouts during initial periods of growth may reduce reproductive tillering and the deleterious effects of accumulated dead material in the sward later in the grazing season (Michell and Fulkerson, 1987). Michell and Fulkerson (1987) observed that the quantities of available green herbage were the same in pastures that had been subjected to low or high SR (1.9 or 3.4 cows/ha) on ryegrass (*Lolium perenne* L.)-white clover (*Trifolium repens*) pastures. However, quantities of dead herbage were greater in the low SR pastures over most of the grazing season. Diet digestibilities between treatments were similar, but production from cows on the low SR appeared compromised due to a reduction of DMI.

Grazing intensity also affects botanical composition and herbage yield of grasses, legumes, and weeds (Brougham, 1960; Michell and Fulkerson, 1987). Composition and yield changes in response to SR are variable depending upon grazing events through the season and emphasize the importance of management in maintaining high quality pastures (Brougham, 1960). Because dead plant tissue (Hodgson, 1985) and fecal matter (Phillips and Leaver, 1985) negatively affect intake and are more prevalent in the fall than in the spring, Phillips (1989) suggested managing pastures for greater sward height as the grazing season progresses.

Fales et al. (1995, p. 88) reported that SR was "a key management variable in determining productivity and profitability of grazing systems but it has not been adequately researched in the USA with high producing dairy cows." Castle et al. (1968) reported that by increasing SR with lactating dairy cows on mixed temperate pastures (primarily ryegrass, timothy, and white clover), herbage utilization was increased; output per land area was increased approximately 28%, though at the expense of individual animal performance. Stockdale et al. (1987, p. 927, citing Stockdale, 1985) stated that "it is not possible to feed cows well on pasture alone if the herbage is to be adequately utilized," and thus SR must of necessity be high. In order to maintain milk production while optimizing pasture utilization, supplements must be fed.

Supplement Effects on Animal Performance with Particular Emphasis on Lactating Cows in Pasture-Based Dairy Systems

Mott (1959) proposed that comparisons of forage quality are best expressed in terms of differences in animal performance and gave guidelines for these comparisons, including (but not limited to) no provision of supplemental energy or protein. However, cows consuming only well-managed temperate pasture had intakes capable of supporting as much as 28 kg of milk/d (Muller et al., 1995), yet the genetic potential of dairy cows for milk production is much greater than this amount (NRC, 1989). Maximizing milk production per animal has been the goal of most of the U.S. dairy industry, and this has been facilitated by the availability of relatively inexpensive concentrate feeds. Thus, forage quality for lactating dairy cows is rarely evaluated by Mott's (1959) guidelines.

The energy requirements of high producing dairy cows cannot be met by forages alone (Galyean and Goetsch, 1993; NRC, 1989). Several studies have shown energy to be the first dietary limitation to optimum performance of cows grazing N-fertilized

pastures (Royal and Jeffrey, 1972; Delgado and Randel, 1989; Davison et al., 1991; Reeves et al., 1996).

To maximize the performance of animals on pasture, supplemental feeds (primarily energy feeds) are required to balance or increase the nutrient supply (Leaver, 1985a,b; NRC, 1989; Muller et al., 1995). Without supplemental energy, milk production may be maintained by excessive mobilization of fat stores. This may have potentially negative consequences in that it may result in metabolic disorders such as ketosis or fatty liver syndrome.

Although milk yield is the typical performance variable measured, reproduction has been shown to be compromised in beef cattle when energy intake is limited (Wiltbank et al., 1964). Muller et al. (1995) noted that reproductive performance of dairy cows also may be compromised without supplemental energy if pastures are high in CP due to the negative relationship between high rumen degradable protein and fertility in the lactating cow (Ferguson and Chalupa, 1989).

Supplement Effects on Production

Though the feeding of supplements is a common practice, production responses to supplement are inconsistent and may not be profitable. Citing Leaver et al. (1968) and Journet and Demarquilly (1979), Meijs and Hoekstra (1984) reported that typical responses were approximately 0.3 to 0.4 kg of milk per kg of supplement fed to cows grazing adequate temperate pasture. In a summary of 12 papers, Combellas et al. (1979) reported similar responses (0.34 kg of milk per kg of supplement) when cows grazed tropical pastures. Davison et al. (1991) reported similar results but speculated that cows

were not adapted to high amounts of supplement (8 kg of DM/d) and that abundant available herbage resulted in greater than normal substitution effects.

Ruiz (1983) suggested that one reason for "poor response to supplementation of grazing cows [in some experiments] is the stage of lactation at which comparisons were made." Ruiz noted that cows on research trials were often beyond peak of lactation and, as cows approached the end of lactation, nutrients may have been more readily partitioned to replenishment of body reserves rather than milk synthesis.

Studies by Jennings and Holmes (1984a) and Stockdale et al. (1987) confirmed the theory of Ruiz (1983). Jennings and Holmes (1984a) found increased total intake and increased milk production with supplement, but a concomitant decrease in milk fat concentration resulted in no difference in FCM production. Cow BW increased with supplement, indicating that the nutritional benefit of concentrate nutrients was not reduced per se, but that nutrients were partitioned toward body reserve repletion. Stockdale et al. (1987, p. 936) reported that "marginal return from feeding [concentrate supplement] decreased as lactation progressed" whereas increases in BW due to supplement were greatest for cows in the latter stage of lactation.

Feeding supplement to cows in the early lactation period may have strong, positive residual effects on milk production in later lactation (Cowan et al., 1975; Martinez et al., 1980). A comparison of supplement provision during the first 10 wk of lactation vs. the whole lactation period showed that when given the same rate of supplement through the whole lactation, cows produced only an additional 181 L of milk in response to an extra 754 kg of concentrate (Martinez et al., 1980, cited by Jennings and Holmes, 1984b). Lack of residual effect (Martinez et al., 1980) may have resulted from

ample HA that provided intake adequate for lower milk production found later in lactation, a response also reported by others (Le Du et al., 1979; Poole, 1987).

Length of study may also be an important consideration for proper interpretation of response to supplement when cows grazed tropical grasses. Jennings and Holmes (1984b) found that in short-term studies (n = 18, average duration = 80 d), the average response to supplements was 0.46 kg of milk/kg of supplement though they noted no "consistent association between level of response to supplementary feeding and stage of lactation," (p. 270). A review by Cowan et al. (1977) suggested responses of 0.3 to 0.6 kg of FCM/kg of supplement were common for studies of less than 60 d in duration.

In studies conducted over most or all of the lactating period, responses to supplement were typically between 0.9 to 1.2 kg of FCM/kg of supplement (Cowan et al., 1977; Cowan, 1985, cited by Davison et al., 1991; McLachlan et al., 1994). However, a review by Jennings and Holmes (1984b) indicates greater variability of response should be expected with complete lactation studies. The authors found the range of response to supplement was 0.10 to 1.80 kg of milk/kg of supplement, with an average response of 0.82 kg of milk/kg of supplement. Jennings and Holmes (1984b) further noted that mean SR was 4.2 cows/ha and average milk yield of unsupplemented cows was 2,560 kg of milk /lactation. Such information serves as a reminder that factors such as pasture and animal management and animal genetic capacity should be included in consideration of response to supplement. For example, a review by Moran and Trigg (1989) comparing response to concentrate feeding between U.S. and Australian cattle indicated that both groups of cows responded well to concentrate up to 2 metric ton per lactation. However, U.S. cattle were able to respond to concentrate up to 3.5 metric ton per year.

Several long-term studies (≥250 d) have shown linear MY increases in response to an increasing supplement rate (Cowan et al., 1977; Davison et al., 1991; McLachlan et al., 1994). Others have reported a curvilinear response (Balch, 1967; Coulon and Remond, 1991, Delaby and Peyraud, 1997).

Other factors which may affect the response to supplement include quality of pasture and supplement, amount of pasture and supplement fed, and the degree to which supplemental feeds replace pasture intake (Stockdale et al., 1987). Although feeding supplement can cause numerous production responses (form and magnitude), the variability of response is associated primarily with the effect of supplement on DMI.

Supplement Effects on Intake

Provision of supplement may increase, decrease or have no effect on forage or total DMI (Moore, 1980). Forage intake may increase if a nutrient imbalance is corrected, leading to increased passage rate due to greater microbial degradation of the forage or stimulation of appetite. Generally, forage intake depressions occur when supplements are fed with forages which have greater nutritive value (Blaxter and Wilson, 1963; Holmes and Jones, 1964; Leaver, 1973; Golding et al., 1976b; Arriaga-Jordan and Holmes, 1986). Large differences in substitution rates have been reported and the effects have greater relation to differences among forages rather than to differences among concentrates (Waldo, 1986).

Golding et al. (1976b) tested the effects of grain supplement on forage intake depression when the supplement was fed at approximately 50% of total digestible energy (**DE**) intake. Bermudagrass harvested at four maturities (4, 6, 8, or 10 wk) was fed as hay to wethers with or without supplement. With increased forage maturity, DE intake

decreased, without or with supplement. Feeding supplement reduced DE intake from hay at all maturities but had the greatest depressing effect on DE intake of wethers fed the highest quality (4-wk maturity) hay. When fed supplement, wethers fed the 4-wk maturity hay decreased hay DE intake by 80 kcal/$BW^{0.75}$ per day, while those fed the 10-wk maturity hay had decreased hay DE intake by 1 kcal/$BW^{0.75}$ per day. The increase in DE intake due to supplement for the 4-wk maturity hay was approximately half that of the 10-wk maturity hay (26 vs. 51 kcal/$BW^{0.75}$ per day for 4- and 10-wk maturities, respectively). Intermediate decreases in hay DE intake with concomitant increases in total DE intake occurred when supplements were fed in combination with hays of intermediate maturity.

Concentrates had limited effects on forage intake in a study by Galloway et al. (1993a). The researchers compared five supplement combinations fed to Holstein steers eating bermudagrass hay in confinement. The hay was of moderate quality, averaging 11.4% CP, 75% NDF, and 52% digestibility. Supplements, fed at 0.75% of BW, were ground corn, dried whey, dried molasses product, or a combination of corn and whey or corn and molasses. Although intake of bermudagrass as a percent of BW was numerically less for all of the three corn-based supplements, only the corn plus molasses treatment significantly decreased bermudagrass intake.

Several researchers have reported forage intake depressions that varied with the amount of supplement fed (Campling and Murdoch, 1966; Tayler and Wilkinson, 1972; Sarker and Holmes, 1974; Cowan et al., 1977; Combellas et al., 1979). Though forage quality may affect the response of intake to supplement, Waldo (1986) noted that “total

dietary DMI is affected very little by forage quality" when diets contain very large (≥ 80% of DM) levels of concentrate.

Sarker and Holmes (1974) fed supplement in increments of 2, 4, 6, or 8 kg OM/d to non-lactating cows grazing ryegrass. Though total OM intake (**OMI**) increased with increasing amount of supplement, the average increase in intake was 0.46 kg of OM/kg of concentrate OM fed.

Combellas et al. (1979) fed 0, 3, or 6 kg of concentrates to lactating heifers grazing *Cenchrus ciliaris* pastures. Across rainy and dry seasons, herbage intake decreased approximately 0.52 kg with each kg of concentrate fed, and the authors noted that this agreed with the range of 0.41 to 0.60 kg estimated from the equations of Holmes and Jones (1964) and Holmes (1976) for a forage of 65% digestibility.

Supplements frequently are fed to animals consuming bermudagrass, and Galloway et al. (1993a, p. 173, citing Galloway et al., 1992) stated that "moderate dietary levels of supplemental grain (e.g., 20 to 30%) can improve nutrient intake and performance by cattle consuming bermudagrass." At greater amounts, nutrient digestion, intake, or both, of the forage portion of the diet can be affected negatively.

Type of supplement fed also is an important factor with respect to substitution effects. Mould and Ørskov (1983) reported that feeding large amounts of rapidly fermentable starch led to decreased intake. Meijs (1986) fed high-starch supplements (containing corn and cassava) or high fiber supplements (containing beet pulp, palm kernel expeller, soybean hulls, and corn gluten feed) to cows grazing predominantly perennial ryegrass swards. Supplement intakes were 5.5 and 5.3 kg of OM/d with forage intakes of 11.5 and 12.6 kg of OM/d for high and low starch treatments, respectively.

Average forage substitution rate for animals receiving the starchy supplement was 0.45 kg of herbage/kg concentrate vs. 0.21 kg of herbage/kg of concentrate for animals receiving the more fibrous supplement. Milk and FCM yields were greater for animals receiving the fibrous supplement, but feeding the starch-based supplement resulted in 0.17 kg greater ADG vs. fibrous supplement.

Similar responses to type of supplement have been found with cows consuming corn silage as the base forage (Huhtanen, 1993). Supplements were crushed barley alone or mixed grain (40%) and pelleted fibrous by-products (60%). Cows eating the fibrous supplement consumed 0.43 kg/d more ($P < 0.10$) silage and more total DM, but lower ME (212.7 vs. 218.0 MJ/d). Milk production increased 1.5 kg/d when animals consumed the fibrous supplement. The author suggested that positive associative effects from the combination of different carbohydrate sources or the greater CP intake (0.20 kg/d) due to the fibrous supplement may help explain greater milk yields. Though liveweight did not change due to supplement and insulin concentrations were not reported, greater plasma insulin concentration for barley supplement have been reported by Miettinen and Huhtanen (1989). This hormonal change would suggest greater partitioning of nutrients to body tissues and may explain the results of Meijs (1986).

Gordon et al. (1993) compared the effects of fibrous or starchy supplements on milk production and energetic efficiency. Fibrous supplements included sugar beet and citrus pulp as well as cottonseed while starchy concentrates contained barley and wheat. Cows were fed the supplements with high- or low-digestibility grass silage. The authors reported greater milk production (23.5 vs. 21.6 kg/d) by cows fed the fibrous supplement. Milk protein percentage was greater with the starch supplement, potentially indicative of

greater microbial synthesis, but milk protein production did not differ due to milk production differences. Partial efficiency of milk production was unaffected by supplement type.

Galloway et al. (1993b) compared provision of soy hulls, corn, or a combination of the two at equal digestible energies (differing amounts in kg/d) to steers consuming bermudagrass hay. Providing hulls resulted in a greater decrease in bermudagrass intake relative to corn or corn plus soy hull supplementation, but total DMI were similar for steers fed the supplemented diets and greater than for steers fed bermudagrass alone. Supplement increased particulate rate of passage from the rumen (avg. 4.71 vs. 4.18%/h), which could have negative effects on digestibility of bermudagrass. However, the overall supplement effect was an increased diet digestibility.

A comparison of a TMR or grain concentrate as a supplement for pasture-fed dairy cattle indicated that a TMR supplement may not be an improvement over concentrate feeds. Welch and Palmer (1997) fed 1) no supplement, 2) 7.3 kg of concentrate/d, or 3) an equal quantity of TMR balanced for 38.5 kg of daily milk to cows grazing unspecified cool-season pastures. Milk production was greatest for concentrate fed cows and least for unsupplemented cows, but milk fat concentration followed an opposite pattern. The researchers speculated that pasture intake "fiber in the TMR probably reduced pasture DM intake" (p. 222).

Supplement Effects on Forage Digestibility

Energy supplements often affect forage digestibility and DMI in a similar manner. Milne et al. (1981) fed sheep increasing amounts of grain concentrate and found a linear decrease in digestibility of ingested herbage. A 9.6 percentage unit decrease (64.3 vs.

54.7%) in true ruminal digestion of cool-season forage DM was reported when lactating dairy cows were fed supplemental corn at 6.4 kg/d. Total tract digestibility of DM was less affected (71.9 vs. 69.9%), however (Berzaghi et al., 1996).

Research with steers (Vadiveloo and Holmes, 1979; Galloway et al., 1993a,b) and sheep (Chenost et al., 1981, cited by Arriaga-Jordan and Holmes, 1986) has shown that when forages are of low to moderate digestibility, supplement often improves overall total diet digestibility, likely due to the greater digestibility of the supplement (Galloway et al., 1993a). Diet digestibility is often unimproved when supplements are fed with high quality forages, however. Arriaga-Jordan and Holmes (1986) studied the effects of concentrate supplementation on herbage digestibility in dairy cattle. Feeding a grain-based supplement to cows eating high quality pasture increased total intake, but reduced herbage intake and depressed digestibility of the herbage consumed, thus reducing the potential nutritional benefit of the concentrates.

Supplements also affect diet digestibility by affecting rates of passage of digesta through the digestive tract. Waldo et al. (1972) were the first to model the relationship between rates of digestion and passage on total digestion: $k_1/(k_1 + k_2)$, where k_1 and k_2 are rates of digestion and passage, respectively. In theory, if passage is 0 then digestion will equal 100% of potential extent of digestion ($k_1/k_1 = 1$). Conversely, if passage is rapid, it will have a large, depressive effect on diet digestion. For example, Tyrrell and Moe (1972) fed increasing amounts of corn grain as a supplement to cows fed corn silage diets. Although intakes increased with supplementation, the decreased digestibility of the diet due to increased passage resulted in decreased concentration of dietary ME.

Forage intake and digestibility in response to supplement feeding also is related to supplement effects on ruminal microbes. Growth of ruminal microbes is reduced in vitro with decreased ruminal pH (Russell and Dombrowski, 1980). Low rates of starch supplementation may increase numbers of cellulolytic microbes, but feeding diets with large concentrations of rapidly fermentable starch may lead to a cascade of events including decreased ruminal pH, reduced cellulolytic microbes, and ultimately, decreased intake (Mould and Ørskov, 1983).

Cellulolysis is decreased not only by reduced pH but also by preferential starch digestion by the microbes (Mould et al., 1983; Hoover, 1986). Mould et al. (1983) fed increasing amounts of barley to sheep, with or without additional bicarbonate salt to buffer ruminal pH. Diets were fed at a fixed rate, just below maximum voluntary intake, so passage should not have confounded the findings. Even when pH was maintained at approximately 6.7, DM digestibility decreased with increasing concentration of barley in the diet, and the depression in apparent DM digestion was greater in sheep fed the more processed barley, suggesting that fiber-digesting microbes preferentially selected starch. Moreover, reduction in cellulolysis in response to starch supplementation was greater when roughages were of lower DM degradability (Mould et al., 1983), which has implications for cows grazing warm-season pastures.

Caird and Holmes (1986, p. 53, citing Jennings and Holmes, 1984a) stated that the "response in intake to concentrates depends on the influence of the concentrate on herbage digestibility." Others have reported that extensively fermented, fiber-based supplements have less negative effects on forage intake and digestion. For example, when soybean hulls were used as a supplement for beef cattle, reductions in forage

consumption were not as evident as when starch-based supplements were fed (Martin and Hibberd, 1990). Klopfenstein and Owen (1987) reported that supplementation with soybean hulls had less effect on ruminal pH compared with supplementation with cereal grains. The lack of starch in soybean hulls may prevent the decreases in fibrolytic activity caused by preferential starch utilization by fiber-digesting microbes (Hoover, 1986).

Other supplement sources such as beet pulp and by-product feeds have also been considered with varying results. Thus, Galloway et al. (1993b) noted that the optimum supplement composition might vary with the forage source with which it is fed.

Though the characteristics of a forage affect both ruminal conditions and absorption of nutrients (Minson, 1990), it should be noted again that the "effects of [forage] quality differences may decrease and even disappear if enough grain is fed. In such a case there would be no effect of forage quality on animal performance" (Golding et al., 1976b). However, extent of production may confound the effect and interpretation of responses to supplement. From work with steers, Joanning et al. (1981) reported that at intake below twice maintenance, associative effects between forage and concentrate might not occur, though this suggestion was based on extrapolations. Ultimately, with high-performance dairy cows, optimizing use of feed supplements will require a balance between improvements in intake and concomitant decreases in digestion.

Besides the changes in digestibility, additional concerns with feeding large amounts of high-starch concentrate may include reduced milk fat concentrations (Huber et al., 1964; Jennings and Holmes, 1984a; Polan et al., 1986; Sutton et al., 1986) and

negative effects due to slug feeding of supplements such as periodic reductions in intake and ruminal acidosis.

Synchronizing Nitrogen And Carbohydrate Supplements To Increase Microbial Protein Synthesis in the Rumen

Loss of Feed Nitrogen in Ruminants

Proteins in pasture forages can be degraded rapidly and extensively by ruminal microbes (Beever et al., 1986a, b; Van Vuuren et al., 1991) and considerable N losses have been reported for animals grazing pasture. For example, steers grazing ryegrass or white clover pastures consumed approximately 0.61 and 1.18 g of N/kg of live weight, and non-NH_3-N (**NAN**) flow to the small intestine was greater with clover diets (0.60 vs. 0.76 g of NAN/kg of live weight for ryegrass and clover, respectively; Beever et al., 1986b). However, the differential between intake N and NAN flow represented a 35% loss of N prior to the duodenum for cows grazing clover pastures and little loss of N for cows grazing ryegrass. Ruminal NH_3 concentrations typically ranged between 20 and 100 mg of NH_3-N/L of ruminal fluid for grass diets, but ranged from 250 to 300 mg of NH_3-N/L of rumen fluid for clover diets.

Similar ruminal N losses (37%) were reported for non-lactating cows consuming unfertilized fresh cool-season pasture grasses (Holden et al., 1994b). Cows were fed fresh pasture, silage, or hay and consumed similar quantities (13.0 to 13.7 kg of DM/d) of the mixed-grass forage. The CP concentration of the forage was approximately 17% in each forage form with the OM:CP ratio ranging from 4.5 to 5.1. Ruminal NH_3 concentrations were greater for cows consuming pasture. The authors, citing work by Ushida et al. (1986), suggested that the greater ruminal NH_3 concentrations might have been related to greater protozoal counts they observed in the pasture-fed cows. Though

bacterial N as a percentage of N flowing to the small intestine was greatest for cows grazing pasture, N flow to the small intestine relative to N intake was least for cows grazing pasture, indicative of the greater N losses. Flows of certain essential amino acids also tended to be less with pasture-fed cows. Holden et al. (1994b) also suggested that diet selection over time may affect fermentation patterns because intake of CP and ruminally degradable protein likely decline with time spent grazing (Chacon and Stobbs, 1976).

Loss of N from the rumen is costly due to significant energetic expenditure associated with urea synthesis and excretion. Urea synthesis and excretion cost approximately 5 kcal/g of N excreted (NRC, 1989). Greaney et al. (1996) estimated that 25% or more of liver oxygen consumption was for the detoxification of ammonia to urea when diets were pelleted alfalfa (2.7% N) or fresh white clover (4.4% N). The authors noted that these energetic costs of N loss were likely underestimated because increased ammonia loading would likely result in increased amino acid catabolism, sodium pump activity and oxidative phosphorylation. In addition to the greater energetic expenditure, additional N costs are incurred with hepatic removal of NH_3 due to amino acid catabolism (Lobley et al., 1995; Greaney et al., 1996). This may further limit animal performance if supplies of essential amino acids are limited.

Though microbial protein is the primary protein source for lactating dairy cows (Glenn, 1994), Leng and Nolan (1984) noted that it alone cannot provide an adequate supply of amino acids to the small intestine for maximum growth and production by the host, as reported by Holden et al. (1994b). This might in part account for reduced persistency observed with grazing dairy cows (Hoffman et al., 1993). To offset these

limitations, some have fed rumen escape proteins, but performance responses to ruminally undegradable intake proteins have been inconsistent, both for cows in confinement and on pasture (Davison et al., 1991; Aldrich et al., 1993; Petit and Tremblay, 1995a,b; Jones-Endsley et al., 1997). Such responses highlight the need for first optimizing ruminal fermentation to maximize microbial protein synthesis (Aldrich et al., 1993; Glenn, 1994).

To maximize "microbial cell yields per unit of nutrient input (e.g., feed materials) the rate of ATP production from fermentation reactions must equal the usage rate by biosynthetic reactions at all times" (Hespell and Bryant, 1979). With adequate ATP (derived primarily from carbohydrate fermentation), rumen microbes can incorporate amino acids into microbial protein (Nocek and Russell, 1988). Thus, providing supplemental energy (typically grains high in carbohydrates) may be an effective way to increase microbial yield and reduce excess N excretion.

Responses to Supplemental Carbohydrate

Responses to providing carbohydrate energy sources are mixed, however. With continuous culture studies, Hoover and Stokes (1991) reported a high correlation ($r = 0.99$) between percent carbohydrate digestion and nonstructural carbohydrate (**NSC**) as a percentage of dietary carbohydrate. However, the correlation of microbial efficiency to NSC as a percentage of dietary carbohydrate was much lower ($r = 0.33$). These results have been confirmed using cows on pasture by Carruthers et al. (1996) who found that "increasing the proportion of NSC in pasture without increasing energy intake did not increase ruminal microbial protein synthesis or increase milk solids production in early lactation."

Nocek and Russell (1988) noted that even "seemingly appropriate amounts of dietary CP and carbohydrate may not provide an ideal balance of protein and carbohydrate to the rumen microorganisms." The authors compared four theoretical diets that were isonitrogenous and isocaloric but which had variable concentration of ruminally available CP and carbohydrate. Theoretical bacterial synthesis and amino acid supply to the small intestine were markedly different among the diets and demonstrated the potential difficulty inherent in formulating diets for maximum microbial production. This challenge may be even greater when forage and concentrates are consumed as individual components such as occurs in grazing systems.

A batch culture study more similar to pasture feeding conditions was conducted to test the effects of asynchronous nitrogen and energy supplies on microbial growth (Newbold and Rust, 1992). Cultures were supplied glucose and urea or corn and soybean meal processed for slow or rapid microbial digestion, respectively. Regardless of substrate, only transient effects of nutrient imbalance on cell yield were reported. Though the mean bacterial population was greater from 5 to 8 h of incubation, populations were similar at 12 h. However, the authors could not rule out end-product inhibition as a reason for similar bacterial mass at the end of the experiments.

Rooke et al. (1987) studied the effects of constant-rate infusions of urea, casein, glucose syrup, or casein and glucose syrup into the rumens of cows consuming ryegrass silage. Infusions did not affect ruminal pH or VFA concentrations, but glucose and the casein-glucose mixture reduced the rumen NH_3-N concentration. Glucose and the casein-glucose mixture also increased the quantities of OM, ADF, NAN, amino acid N, and microbial N entering the small intestine, indicating that microbial yield was increased but

at the expense of fiber digestion. Similar results were found by England and Gill (1985) who added sucrose to grass silage diets at 50, 75, 100, and 150 g/kg of silage DM. Silage DMI was reduced, but not total DMI. With increasing proportions of dietary sucrose, a corresponding decrease in cellulose digestion was observed. The results indicated that the benefits of N utilization were offset by the decrease in diet digestibility, perhaps due to the rapid solubility of the sucrose.

Phillips (1988) suggested corn silage would be "a suitable nutritional complement" to herbage of variable energy and high CP concentrations. An experiment by Holden et al. (1995) indicated that supplemental silage fed to cows grazing pasture might have altered ruminal fermentation and reduced N load because silage supplement also reduced concentrations of plasma urea N from 29.6 to 27.3 mg/dL. This could not be determined by the authors, however, because the change in plasma urea N concentration with silage treatment could have resulted from better N utilization or decreased intake of ruminally degradable protein. Production responses were unaffected by supplemental silage.

In some experiments, microbial utilization of forage N was not markedly improved by supplementation with barley (Thomas et al., 1980; Rooke et al., 1985). Greater intraruminal N recycling due to increased ruminal protozoal number has been implicated in the lack of N utilization by microbes (Chamberlain et al., 1985). Substitution with fibrous concentrates such as beet pulp and distiller's solubles for barley has resulted in increased duodenal NAN primarily due to increased feed N flow (Huhtanen, 1988, 1992) with concomitant increase in milk production and milk protein yield (Huhtanen, 1987; Ala-Seppälä et al., 1988).

The effects of corn supplementation on intake and digestion characteristics in lactating cows consuming primarily orchardgrass (*Dactylis glomerata* L.) and white clover were studied by Berzaghi et al. (1996). Provision of supplement decreased ruminal NH_3 (17 vs. 22 mg/dl) and increased N recovery at the duodenum (86.7 vs. 75.3% of N intake), though total tract N recovery was reduced with supplementation (71.9 vs. 78.8%). Digestibility of NDF also was reduced with supplementation, suggesting that corn had negative effects on fiber digestion. Differences in microbial flow to the duodenum were not significant.

Effects of Supplement Feeding Frequency

Feeding frequency may also alter ruminal fermentation patterns, improve nutrient synchrony, and enhance microbial growth. Gustafsson et al. (1993) studied more than 38,000 records of Swedish cows and found that feeding concentrates 4 or more times per day resulted in 3 and 7% (by year) increases in milk production compared with feeding twice per day. Their study indicated that feeding frequency positively affected milk production of primiparous cows with low ME intakes but that this was less of a factor as ME intake increased. Increasing feeding frequency from 1 to 2 times per day for dairy cows grazing tropical pastures was shown to increase milk production approximately 11% (McLachlan et al., 1994), but no milk production responses were observed in a comparison of providing supplement 2 or 4 times per day to cows grazing cool-season pastures (Hongerholt et al., 1997).

McLachlan et al. (1994) fed 0, 2, 4, 6, or 8 kg of a cracked-corn, meat-meal supplement and reported that the FCM response was greatest with 6 kg of supplement/d and pasture substitution rates were less when the supplement was provided twice daily.

From these results the authors inferred that more frequent feeding resulted in more stable ruminal fermentation patterns, and that cellulolytic activity was closer to optimum. However, increased milk protein percentage and greater milk fat concentrations (which could support the hypothesis of increased microbial growth and cellulolytic activity with increased feeding frequency) were not observed.

Kolver et al. (1995) fed a supplement either with the base forage (a cool-season pasture grass) or four hours after forage feeding. With synchronous feeding they found less diurnal variation in ruminal pH, but average pH was lower (6.06 vs. 6.17). Synchronous feeding reduced concentrations of ruminal NH_3 at 3 and 5 h post-feeding, but N retention for milk and growth were unaffected.

In a review, Robinson (1989, p. 1199) noted that "although improved efficiency of rumen fermentation in frequently fed cows seems unlikely to result in increased milk yield in research studies, it can result in increased milk energy output due to increased fat yield in situations where the combination of infrequent feeding and high inclusion of rapidly fermentable dietary components results in perturbation of rumen fermentation sufficient to depress milk fat output. In addition, some evidence suggests that maintenance of body condition, often a critical problem in high producing herds may be better maintained with more frequent feeding." Production benefits due to improved ruminal fermentation efficiency are likely to be quantitatively small when compared with production gains due to the increased intake associated with greater feeding frequency (Robinson, 1989).

Though McLachlan et al. (1994) did not report changes in body condition, their results of increased FCM and reduced forage substitution with increased feeding frequency support the observations of Robinson (1989).

Hongerholt et al. (1997) fed a supplement 2 or 4 times per day and reported that BW change and non-esterified fatty acids (**NEFA**) concentrations were unaffected when grain intakes were similar across treatments. In contrast, feeding 6 rather than 2 times per day resulted in greater milk fat concentrations and decreased concentrations of plasma NEFA (Sutton et al., 1986), indicative of enhanced cellulolytic activity and energy availability from the diet.

Effects of Timing of Supplement Provision Relative to Forage Intake

Timing of forage and concentrate provision relative to each other may affect intake and performance. Morita et al. (1991; cited by Morita et al., 1996) reported that steers ate more roughage when concentrate was fed after roughage provision. Work from Germany (Voigt et al., 1978, cited by Robinson, 1989, p. 1205) indicated that providing grain supplements before feeding roughage (chopped ryegrass) had different effects upon ruminal pH and digestion of cellulose depending upon the fermentability of the grain. Barley, a rapidly fermented grain, caused a greater depression in ruminal pH than corn, a more slowly grain. Feeding the ryegrass before the grains caused a greater increase in forestomach whole-diet cellulose digestion if barley was the grain supplement (63.6 vs. 75.0%) rather than corn (72.1 vs. 78.3%). Differences in ruminal cellulose digestion were unaffected by feeding sequence if the ryegrass was pelleted and total diet digestion was reduced. Morita et al. (1996) also noted that roughage consumption and fiber

digestibility in the rumen were greater when cows ate roughage before concentrate rather than in the reverse order.

Timing might also be important relative to ruminal heat production. Russell (1986) reported that adding pulses of glucose to glucose-limited cultures immediately doubled heat production with little increase in cell protein. In addition to reduced efficiency of microbial protein production, consumption of primarily soluble carbohydrate-based supplements in asynchrony with dietary protein might increase ruminal heat. Heat in the rumen negatively affects intake of DM and water and alters ruminal fermentation patterns (Gengler et al., 1970). A 3 °C increase in rumen temperature (from 38.0 to 41.3 °C) resulted in a 14% decrease in feed intake (13.2 vs. 11.4 kg/d for control and treatment cows, respectively) in the study by Gengler et al. (1970).

Additional Energy and Protein Supplements for Animals on Pasture

Fats

Fat feeding may improve milk production but has potential for negative side effects with respect to microbial fermentation, growth, and feed digestion (Emery and Herdt, 1991). Fat feeding to lactating cows typically has been limited to mixed rations, and information on feeding fats to cows on pasture is limited.

King et al. (1990) compared production from cows grazing ryegrass pastures and receiving no supplement, 3.5 kg of a grain-based pelleted concentrate, or 3.8 kg of pellets containing 0.5 kg of added fatty acids (primarily palmitic, stearic, and linoleic acids). Diets were not isocaloric. Forage intakes were similar and were estimated at 17.0, 16.3, and 15.6 kg of DM/d for control, concentrate, and concentrate plus fatty acid treatments.

Total intake was an average of 2.5 kg/d greater for supplemented cows. Production of milk, 4% FCM, and milk protein were not different between concentrate treatments but were greater than for the unsupplemented treatment. Cows fed fatty acids produced greater quantities of milk fat. Volatile fatty acids in ruminal fluid were essentially unchanged between concentrate treatments, indicating that the fatty acids used did not affect microbial function. However the low amount of added dietary fat and the small percentage of which was unsaturated fatty acid would not be expected to significantly hinder microbial function (Jenkins, 1993).

Escape proteins

In a review, Oldham (1984) noted that supplemental proteins might directly affect control of food intake in ways not directly related to improvements in digestibility. This has been shown by Froetschel et al. (1997) who reported that ruminal undegradable proteins contain peptide sequences that may increase gut motility.

Because of the rapid and extensive degradation of proteins in lush pastures (Beever et al., 1986a,b), some researchers have explored the utility of supplementing cows with less ruminally degradable sources of protein. Jones-Endsley et al. (1997) compared amounts (6.4 vs. 9.6 kg/d) and concentrations (12 and 16% CP) of protein supplements for lactating dairy cows. The 16% supplement appeared designed to provide additional ruminally undegradable protein, but this was not made clear by the presented feed analysis. Amount of supplement did not affect forage intake, but animals consuming the 16% CP concentrate tended to consume more forage (1.6 kg/d) than did those fed the 12% CP supplement.

Hongerholt and Muller (1998) also found no response of grazing, lactating cows to increased dietary ruminally undegradable protein, but Stobbs et al. (1977) reported that escape protein from protected casein stimulated intake. When Davison et al. (1991) provided meat and bone meal to lactating cows, they were not able to measure forage intake changes. However, by calculations of energy requirements for observed milk production and weight changes, the authors determined that forage intake was likely increased. Consumption of meat and bone meal did not result in greater milk yield, but did result in less ($P = 0.068$) BW loss over the first 100 d of the trial and greater ($P = 0.054$) gain over the entire lactation. The authors concluded that "responses to protein supplements . . . vary with the type of pasture, the level of grain or energy supplement fed and the level of pasture on offer" (Davison et al., 1991, p. 162).

Effect of Supplements on Grazing Behavior

Several researchers have reported reduced grazing time with supplementation. Sarker and Holmes (1974) fed 2, 4, 6, or 8 kg of concentrate supplement/d. They reported large decreases in GT (an average of 28 min/kg of supplement) with supplementation. Although total OM intake increased 2 kg from the low to the high supplementation rate (11.5 vs. 13.6 kg of OM/d), herbage OM intake decreased from 9.9 to 7.4 kg of OM/d.

Cowan et al. (1977) fed a 4:1 corn:soybean meal concentrate at 0, 2, 4, or 6 kg/d to cows grazing green panic (*Panicum maximum* var. trichoglume) and glycine (*Glycine wightii* cv. 'Tinaroo') pastures. They reported decreased grazing time with increased supplement (23 min/d per kg of supplement fed) during autumn and winter months (time of reduced HA), but not during summer. Available pasture increased with increasing

amount of supplement fed. Estimates of forage mass excluded dead material. Average mass of DM harvested increased 188 kg/ha for each kg increase in concentrate fed, indicative of reduced forage intake. Herbage on offer ranged from 4000 to 6000 kg of green DM/ha in summer to 500 to 1500 kg of green DM/ha in winter (below the "forage not limiting intake level"). Average length of lactation was greater for supplemented cows (275 d) compared to those of 0 (222 d) or 2 kg/d (252 d) supplement groups. Cows assigned to 0 or 2 kg/d treatments had to be removed from treatment early due to excessive weight loss.

A study of heifers grazing *Cenchrus ciliaris* pastures showed that grazing time decreased 11 min/kg of supplement fed (Combellas et al., 1979). Heifers received a high energy, high protein concentrate at 0, 3, or 6 kg/d. Rate of biting, total bites, and intake per bite were also decreased. Though not significant, the number of grazing periods was numerically greater with increased rate of supplementation.

Pulido and Leaver (1997) reported decreased GT of 11 min/kg of concentrate, though effects were much more dramatic when concentrate fed was greater than 6 kg/d. For 0, 6, or ad lib kg of daily concentrate intake, GT were 531, 526, and 381 min/d and rates of forage intake were 31.4, 25.8, and 20.7 g/min. Forage intake decreased 0.69 kg/d for each kg of concentrate consumed.

A study with beef steers (Adams, 1985) indicated that timing of supplement feeding affects grazing behavior and forage intake. Steers grazing Russian wild ryegrass (*Elymus junceus*) in Montana received forage only (control) or morning or afternoon feedings of corn supplement (0.3 kg of supplement/100 kg of BW). Though supplemented steers ate less forage than steers on the control treatment, comparison

between morning and afternoon feedings indicated greater forage intake with afternoon feeding (2.6 and 2.9 percent of BW for morning and afternoon feedings, respectively). Total intakes were not different among the three treatment groups, but forage intake and total intake were greater for afternoon-supplemented steers in comparison with morning supplemented animals. Feeding supplement to steers in the morning resulted in a 24% decrease in forage intake/h of grazing time in comparison with control and afternoon feeding treatments (Adams, 1985).

Reid (1951) noted that DMI and grazing time are not necessarily correlated. Similarly, Krysl and Hess (1993) noted that a decrease in grazing time does not necessarily mean a decrease in forage intake because harvest efficiency (defined as g of forage OMI/kg of BW per min spent grazing) may change. Work of Barton et al. (1992) confirmed these ideas. The authors observed grazing behavior of dairy steers fed supplemental cottonseed meal at 0 or 2.5% of BW in the AM or PM. The steers reduced grazing time on intermediate wheatgrass (*Thinopyrum intermedium* Host) pastures by approximately 1.5 h when provided cottonseed meal supplement, but forage intakes were not different across treatments. Steers receiving cottonseed meal had numerically greater forage intake.

Interactions of Supplement and Herbage Allowance on Performance of Lactating Cows in Pasture-Based Dairy Systems

The two main factors considered to cause the variable responses to supplement are forage availability and forage nutritive value. Work by Blaser et al. (1960) demonstrated that concentrate supplements were used more efficiently when herbage was limited.

To investigate the interactions of herbage availability and level of concentrate supplementation on OMI, Meijs and Hoekstra (1984) stocked lactating Friesians on perennial ryegrass pastures at 16.3 or 24.8 kg of pasture OM/cow per d. Values for HA are 2-yr averages within treatments. Three rates of concentrate (1, 3, or 5 kg/cow per d in 1981 and 1, 4, or 7 kg/cow per d in 1982) were fed. Greater herbage intake was reported at the greater HA (13.6 vs. 11.3 kg of OM/cow per d for the greater and lesser HA, respectively). Increasing concentrate intake negatively affected forage OMI. This was primarily due to the decrease in forage intake by cows on the greater HA treatment (forage by concentrate interaction). Forage OMI of 14.9, 13.6, and 12.3 kg/cow per d were reported for cows fed the low, medium and high concentrate rates, respectively, for cows on the greater HA treatment, whereas forage OMI decreased only from 11.4 to 11.0 kg/cow per d with increasing concentrate for cows on the lesser HA treatment.

"Relatively few experiments have been conducted on tropical pastures to determine objectively the relationship between herbage availability and the performance of dairy cattle. There is therefore little evidence on which to determine the pasture conditions under which supplementary feeding might be most efficiently employed" (Jennings and Holmes, 1984b, p. 270). Little research has been published on this topic in the last 15 years.

Cowan and Davison (1978) investigated effects of supplementing maize (0 or 3 kg/d) to cows grazing tropical pastures of mixed forage species at 1800 or 3300 kg of DM/ha. Milk production was increased from 6.5 to 9.3 kg/cow per day with supplement offered to cows assigned to the lower level of HM but was unaffected by supplement (13.0 kg/d) offered at the greater level of HM.

Two Perennial Forages for Lactating Cows in Pasture-Based Dairy Systems in the Southeast

Bermudagrass

Bermudagrass is one of the most extensively grown improved, perennial, warm-season forages for the Southeast. According to G. W. Burton, bermudagrasses '"occupy more than half the pasture acreage in the southern United States"' (cited in Adams, 1992, p. 19). First introduced to the U.S. in 1751 (Burton and Hanna, 1995, citing the diary of Thomas Spalding), bermudagrass has been the subject of much research. Numerous improved cultivars of the grass have been released since the 1940s (Burton and Hanna, 1995), and a review of the literature reveals improvements in both yield and digestibility (Monson and Burton, 1982). Today, more than 5 million hectares in the Southeast have been sprigged with improved bermudagrasses, with many more supporting common bermudagrass (Burton and Hanna, 1995).

Though well adapted to much of the region, bermudagrasses typically have high concentrations of NDF and low concentrations of NE_L and digestible nutrients (West et al., 1997). A compilation of 18 experiments in which bermudagrass hay "harvested at vegetative to mature growth stages, obtained from local producers and grown with a variety of management practices" was reported by Goetsch et al. (1991, p. 2635). Mean NDF concentration was 74.5% with a range of 65.6 to 86.7% (DM basis). Though mean OM digestion was 54.9 %, the range of OM digestion was quite wide, from 27.5 to 75.4%.

Bermudagrass yield responses and nutritive value characteristics are affected by numerous factors, including frequency of defoliation (grazing or clipping), fertility, temperature, season, and location, and responses vary by cultivar (Wilkinson et al., 1970;

Jolliff et al., 1979; Henderson and Robinson, 1982; Holt and Conrad, 1986; Adjei et al., 1989). Soil moisture also has been implicated as a factor affecting quality of warm-season grasses (Henderson and Robinson, 1982; Pitman and Holt, 1982).

Yield typically increased with decreased frequency of defoliation (Decker et al., 1971; Holt and Conrad, 1986; Adjei et al., 1989) though this was not reported by Ethridge et al. (1973). Conversely, *in vitro* digestibility decreased with decreased defoliation frequency (Decker et al., 1971; Holt and Conrad, 1986; Jolliff et al., 1979), but the magnitude of change in digestibility has been inconsistent (Hussey and Pinkerton, 1990). Data from Holt and Conrad (1986, p. 435) indicated "that both yield and dry matter digestibility cannot be maximized by manipulating harvest or utilization frequency, necessitating a compromise in one or both in any management situation."

In pasture systems, both digestibility and availability of forage influence animal performance. As digestibility decreases, more forage must be consumed to maintain animal gain, and the upper limit of productivity will be reduced (Duble et al., 1971). Forage quality, as determined by intake, nutritive value and efficiency of utilization, is well demonstrated by work of Greene et al. (1990). Stocker performance was compared using four different bermudagrass cultivars. Though the cultivar 'Grazer' did not produce the greatest forage DM yields, animal output per unit land area with Grazer was approximately 18% greater than the average production with the other cultivars ('Brazos', Coastal, and Tifton 44).

The varying nature of cultivar responses makes finding an appropriate compromise between maximum yield and greatest nutritive value more difficult. Optimum will likely depend on production aims. For example, Adjei et al. (1989)

investigated the response of three bermudagrass cultivars to grazing at 2, 4, 6, and 8 wk frequencies within seasons (Winter/Spring and Summer/Fall). Yield response of Callie 35-3 (now cv. 'Florakirk') to grazing frequency was quadratic in nature. Maximum yields for both Callie 35-3 and Tifton 78 occurred at the 6-wk grazing interval, with yields of 2.6 and 3.6 t/ha for the respective cultivars. A linear response to grazing was observed for Tifton 79, with a maximum yield of 3.5 t/ha occurring at the 8-wk grazing frequency. Conversely, as grazing frequency decreased, in vitro organic matter digestibility (**IVOMD**) declined in a linear fashion for Callie 35-3 and exhibited both linear and quadratic characteristics for Tifton 78 and 79 depending on season. For the Tifton cultivars, greatest digestibility occurred at the 4-wk grazing frequency. Concentration of CP also decreased with decreased grazing frequency for all cultivars with the nature of the responses dependent on season and cultivar.

Holt and Conrad (1986) investigated yield and digestibility responses to frequency of harvest among several varieties of bermudagrass and one stargrass (*C. nlemfuensis* Vanderyst) cultivar (Tifton 68). Although Coastal bermudagrass had the greatest seasonal yield at all clipping frequencies (average of 15.8 metric T/ha), its IVDMD was least at all clipping frequencies (average of 54.8% IVDMD). The stargrass cultivar had intermediate yield (average of 13.8 t/ha) and greatest digestibility (average of 65.4% IVDMD) at all clipping frequencies. The greater IVDMD for Tifton 68 resulted in that cultivar producing the greatest quantity of digestible OM. The best compromise between yield and digestibility for all cultivars was at approximately 4 wk of regrowth.

Many studies of the effect of fertilization on bermudagrass yield and nutritive value have been conducted. Typically, increased CP concentrations were reported with

increasing N application (Monson et al., 1971; Monson and Burton, 1982; Thom et al., 1990). Good fertilization is essential to production of quality bermudagrass. Stallcup et al. (1986) fertilized bermudagrass pastures at 0 to 200 kg of N/ha in 50 kg increments and reported that CP concentrations in bermudagrass fertilized with 0 and 50 kg of N/ha were 11.4 to 14.3%, respectively. Although apparent DM digestibility increased slightly (61.3 to 62.0%), CP digestibility increased from 54.2 to 63.6%. When the hays were fed to steers, the difference in N retention (measured as a percent of N fed) was quite large (2.8 vs. 21%, respectively). Increasing the rate of N application above 50 kg of N/ha had more modest positive effects on the variables measured. Monson and Burton (1982) investigated the effect of two levels of N fertilization (336 or 672 kg/ha) and cutting frequency (1, 2, 4, or 8 wk) on yield, quality, and persistence of eight bermudagrass cultivars. Digestibility increased with increased N application with weekly harvests. Significant interactions between harvest frequency and genotype in response to N also were noted. Besides increasing CP and yield, N fertilization also has been shown to increase carotene and xanthophyll concentrations in bermudagrass (Monson et al., 1971).

Ocumpaugh (1990) noted that if legumes are used, chemical N sources are not a necessity for bermudagrass production. He reported that when Coastal bermudagrass pastures were overseeded with sub-clover (*T. subterraneum*) or arrowleaf clover (*T. vesiculosum*) they produced as well as similar pastures receiving two applications of 56 kg of N/ha. In years of plentiful rainfall grass-legume pastures out-yielded grass-N pastures.

Singular use of N fertilizer may not be effective for bermudagrass production. Welch et al. (1981, cited by Pratt and Darst, 1986) reported that yields with N

fertilization were 50% of those when both N and K were applied. Pratt and Darst (1986) also indicated that response to K fertilization was not always immediate. In their work, K deficiency was seen (vis-a-vis large decline in yield) in the third year of study, and they emphasized the need for long-term observation.

Effects of other fertilizers on animal responses have been investigated. Mathews et al. (1994b) fed non-lactating cows chopped Tifton 78-common bermudagrass hays which had or had not been fertilized with S (gypsum). The authors reported a 30.4 percentage unit increase in the apparent digestibility of S (vs. unfertilized control) and a 10.6 percentage unit increase in the apparent digestibility of lignin. Apparent N digestibility slightly increased with S fertilization. Digestibility of ADF and NDF tended ($P = 0.18$) to be increased by 1.5 percentage units, and DMI also tended ($P = 0.14$) to be increased with S supplementation.

Henderson and Robinson (1982) grew bermudagrass in chambers to study the effects of differing light intensity, moisture, and temperature on bermudagrass harvested at 14 or 21 d. Yield increased with increased temperature and with increased photon flux density, and in vitro digestibility decreased with increased temperature. When soil moisture was low, light level did not affect forage digestibility across the array of temperatures. Similarly, increased age reduced digestibility to a lesser degree under moisture-limited conditions.

Seasonal effects on digestibility have been observed. Forage digestibility typically is greatest in spring, declines in summer and increases in late summer or early fall (Carver et al., 1978; Holt and Conrad, 1986), though this pattern is not always observed (Guerrero et al., 1984). Holt and Conrad (1986, p. 435-436) noted that

differences in digestibility were unrelated to age at harvest, and that changes in IVDMD "apparently are related to environmental conditions not clearly understood under field conditions." Adjei et al. (1989) also reported that forage nutritive value typically was greater in fall than in summer and differences between cultivars within seasons were observed as well. Animal performance often mirrors these changes (Greene et al., 1990).

Holt and Conrad (1986) investigated decreasing leaf proportion as a source of decline in forage digestibility because leaves are usually more digestible than stems. Leafiness decreased with age but, though the decline in leaf proportion was a significant factor, it explained less than 50% of the decline in forage digestibility ($r^2 = 0.44$). The authors noted that stem digestibility was a likely factor in cultivar digestibility differences, but this was not explored. "Genotype and seasonal effects on [IVDMD] were greater than and largely independent of leaf effects when plant material was all the same chronological age" (p. 435). Similar results with respect to leaf proportion were observed by Mathews et al. (1994a). They investigated IVOMD and nutrient concentration of 'Callie' bermudagrass in response to four methods of harvest. Pastures were stocked continuously, rotationally stocked in short and long rotations, or cut for hay. Leaf lamina as a percentage of the plant material sampled was least with continuous stocking (33.5% across years) and averaged 47% with the other three methods. However, the weighted mean of IVOMD was relatively stable (56.5%), not differing by more than 3.2 percentage units.

Location also determines the productivity and quality of bermudagrass in as much as it combines such factors as rainfall or soil moisture, ambient temperature, soil characteristics, and incident light. For example, though Adjei et al. (1989) did not

specifically test genotype by location, their research indicated that Tifton 78 was unsuitable for central Florida conditions even though it had been released and was "finding some use in Georgia."

Numerous investigators have studied the suitability of use of bermudagrass as an animal feed. Typically, the grass is used more in extensive feeding systems such as pasture for beef cattle or dry dairy stock.

Stocking rates on bermudagrass may have a large influence on animal performance once some critical level is reached. Working with a biophysical model, Parsch et al. (1997) simulated forage production responses to a range of beef cattle SR. According to the model, with improved bermudagrass pastures weight gain per head is essentially unaffected by grazing intensity until a critical SR (6 head/ha) is reached. Bransby et al. (1988, p. 278) also reported that "grazing systems on bermudagrass appear to be well buffered against changes in grazing intensity" across a wide range of stocking rates and available herbage.

The interaction of forage and SR with continuously stocked bermudagrass pastures was investigated by Guerrero et al. (1984). Forages were Callie, Coastal, and three experimental hybrids. Stocking rates varied by cultivar but the range averaged from 4.6 to 11.0 steers/ha. Forage digestibility was increased with increasing SR, and greater digestibility occurred primarily at medium and heavy SR. However, ADG decreased as available herbage declined, and cultivar differences in digestibility and yield were observed.

Roth et al. (1984, 1990) studied bermudagrass growth, morphology, and compositional responses at four different HA under continuous stocking management.

Decreased HA affected leaf chemical characteristics and the proportion of leaf in the HM. Leaf NDF decreased from 75.2 to 71.3% from high to low HA, and the average proportion of leaf in the HM decreased by 51.6 and 39.7% for low and high HA treatments, respectively.

Leaf proportion in the diet was unaffected across grazing pressures (82.7% for low and 78.5% for high pressures), however, demonstrating diet selectivity of the grazing animal. Animals also showed selectivity for leaves of greater quality as the concentration of NDF in leaves selected was less than that in leaves in the standing herbage. With the lower HA treatments, the proportion of dead material increased as leaf declined during the hotter months. The dead material consisted primarily of uprooted stolons and dead stems, and their disappearance later in the grazing season was due to consumption.

Although dead herbage is not high quality, the concentration of NDF in the dead herbage of the low HA treatment was approximately 9.0 percentage units less than that of the other treatments. As HA decreased, NDF concentration of the herbage was reduced in the two pastures with the lowest HA compared with the two pastures with the greatest HA. Moreover, reductions in NDF concentrations with decreased HA were observed in all herbage components, and particularly in the senesced herbage.

Other studies (Arnold, 1960; Hamilton et al., 1973; Adjei et al., 1980) have not shown the positive relationship between HA and NDF concentration of the herbage or the diet found by Roth et al. (1990). The latter noted that the previous studies were conducted using greater HA, however.

In 1993, a new cultivar, Tifton 85, was released (Burton et al., 1993). The grass is actually an interspecific hybrid between bermudagrass and stargrass (Tifton 68), and it

produces "an abundance of stems and leaves in spring, followed by more vegetative growth later in the season" (Hill et al., 1993, p. 3222). The authors reported greater NDF concentrations in the forage earlier in the grazing season and suggested that this might be due to the cultivar's growth habit.

Tifton 85 has "[r]apid growth rate and high IVDMD values relative to other bermudagrass hybrids" (Hill et al., 1993 p. 3219). Hill et al. (1993) tested Tifton 85 grown in small plots and found that it produced greater quantities of DM with greater digestibility than all other cultivars in the comparison. In comparison with Coastal bermudagrass, [at one time the predominant cultivar in the Southeast (Holt and Conrad, 1983)], Tifton 85 produced more than 25% more DM (16.7 vs. 13.3 t of DM/ha) the and forage was more than 12% more digestible (58.8 vs. 52.3% IVDMD).

Hill et al. (1993) also compared Tifton 85 with Tifton 78 in a grazing study. Tifton 78 is a cultivar widely used because of its relatively high digestibility and yield. The researchers maintained HM of both forages at approximately 2500 kg of DM/ha over 2 yr and sampled esophageally fistulated steers to estimate forage nutritive value characteristics. Tester steers and variable SR also were used to determine ADG and to calculate grazing d/ha. Steers grazed 169 d each year, and though the ADG with the two forages were similar (0.67 vs. 0.65 kg/ for Tifton 85 and 78, respectively) Tifton 85 supported in excess of 500 more grazing days over the 3 yr of the study. The BW gain/ha was 46% greater for steers grazing Tifton 85 as a consequence (1160 vs. 790 kg/ha). Hill et al. (1993, p. 3224) noted "a strong tendency for Tifton 85 to remain more productive later in the grazing season than Tifton 78 did." This translated into slightly greater rates of BW gain in August and September.

Mandebvu et al. (1998) compared DM and NDF digestibilities of first and second cuttings (3.5 wk of growth) of Tifton 85 hay with that of Coastal bermudagrass hay of 4 wk growth. The IVDMD was reported as 63.6, 59.9, and 52.0% for the first and second cuttings of Tifton 85 and the Coastal bermudagrass hay, respectively. The NDF digestibilities were 61.4, 58.5, and 47.5%. First-cut Tifton 85 had a greater potentially digestible NDF fraction in whole forage (77.9 vs. 67.1%) and in extracted NDF (81.5 vs. 70.7) than did Coastal bermudagrass.

Much literature details performance of beef animals grazing bermudagrass pastures, with some information released comparing Tifton 85 with Tifton 78 (Hill et al., 1993), but information regarding use of bermudagrass for grazing dairy animals is limited. A study by Martinez et al. (1980, cited by Jennings and Holmes, 1984b) may have overpredicted the potential use of bermudagrass as a pasture forage for dairy cows. The authors reported that cows grazing Coast-cross I bermudagrass produced 4125 kg of milk/cow per yr without supplementation.

West et al. (1997) indicated that Tifton 85 may be suitable for confinement dairies, but no information is presently available regarding use of Tifton 85 by lactating cows in grazing systems without or with supplemental feeds. In the study by West et al. (1997), 3.5% FCM yields were not different for cows fed diets of either 15 or 30% bermudagrass or alfalfa hays. Results suggested that the NDF digestion of Tifton 85 was more rapid and more extensive than that of alfalfa or corn silage components of the diets.

Comparisons of Grasses and Legumes

The high concentrations of NDF and low concentrations of digestible nutrients associated with warm-season perennial grasses limit their desirability for use in animal

production systems. Many have looked to forage legumes for suitable alternatives to grasses because animal performance is often greater when legumes are fed (Rattray and Joyce, 1974; Thomas et al., 1985; Beever et al., 1986b; Hoffman et al., 1998). The following discussion primarily will consider cool-season perennial legumes, because few warm-season perennial legumes have proven suitable for intensive grazing systems.

Regarding chemical composition, legumes typically have greater concentrations of protein than grasses, with a larger percentage of the protein being ruminally degradable (Beever et al., 1986a; Glenn, 1994). The soluble portion of legume CP also is different, having more amino acids and peptides than that of grasses (Glenn et al., 1989). Legumes generally have less NDF than grasses, and the composition of NDF in legumes is markedly different. Legumes have less hemicellulose, typically less cellulose, more lignin and more pectic substances (Van Soest, 1965) than grasses.

In vitro digestibility studies indicate that legumes typically have a greater rate but lesser extent of digestion in comparison with grasses (Smith et al., 1972). Glenn (1994) noted that, relative to alfalfa, proportionately more grass NDF typically is digested in the rumen. A review of several comparisons of alfalfa and orchardgrass fed to growing animals indicated that total tract digestibility of orchardgrass was 94% that of alfalfa (Glenn, 1994). In comparisons of alfalfa with ryegrass or orchardgrass, researchers typically have found greater true fiber and DM digestibility for the grasses (Holden et al., 1994a; Hoffman et al., 1998), but the greater DM digestibility may in part be related to the lower intakes of cows on the grass-based diets.

Holden et al. (1994a) fed diets of 55 or 66% forage (orchardgrass and alfalfa hays, respectively) which were formulated to have equivalent NDF concentrations. Lactating

cows consumed 17.5 and 15.1 kg of OM/d for the alfalfa and orchardgrass diets, respectively, and total tract digestions of NDF, ADF, and DM were greater for cows fed the grass diets. In the study by Hoffman et al. (1998), lactating cows were fed diets based on 70% inclusion of alfalfa or perennial ryegrass silage. Intake of DM was greater when cows ate alfalfa silage (22.5 vs. 20.3 kg of DM/d), though true digestibility of NDF and DM was greater for the ryegrass silage-based diet. In both studies, milk production was greater with the alfalfa-based diet.

In a comparison of steers grazing pure stands of ryegrass or white clover, Beever et al. (1986b) reported a nearly 25% greater DMI of the clover pasture (26.0 vs. 20.9 g/kg of LW). Although intakes are generally greater with legumes, the better performance typically associated with their consumption may not be only an intake effect. Glenn (1994, citing Tyrrell et al. 1992 and Varga et al., 1990) noted that the large differences in digestible OM composition must have some effect on the composition of absorbed nutrients.

Differences in digestible OM composition likely contribute to the greater efficiency of ME use associated with legume consumption (Armstrong, 1982). Greater energetic efficiency of lactating cows fed alfalfa in comparison with orchardgrass was reported by Casper et al. (1993). The authors fed ensiled forages (direct-cut and treated with formaldehyde and formic acid) with two high-starch concentrate sources (barley or corn grain). Intakes of DM and ME and the digestibility of the DM were all greater for the alfalfa-based diets. Although heat production was greater when cows consumed alfalfa, heat production per unit of ME intake was greater for the orchardgrass diets. The

greater heat production/ME likely indicated “an increased energy cost associated with digestion” of orchardgrass.

Although the greater DMI and efficiency of utilization reported with legumes is desirable, legume use in pasture systems in warm climates often has been limited. Few perennial legumes have been satisfactorily productive or persistent in forage systems in subtropical regions of the humid Southeast, and some researchers have argued that legumes have little place in production systems in the region (Rouquette et al., 1993). To date, insects, nematodes, phytopathogens and poor persistence under grazing conditions have relegated tropical legumes to limited roles in forage production systems in the tropics (Maraschin et al., 1983).

Rhizoma Peanut

One legume with promise for the region, however, is rhizoma peanut (*Arachis glabrata* Benth.). The legume is fine-stemmed and leafy, with potential for use in grazing or stored-forage production systems (Prine et al., 1981). Introduced to Florida from Brazil in 1936 and first distributed to commercial growers in 1978 (Prine et al., 1986), most acreage expansion has occurred since 1980 (French, 1988). In 1990, an estimated 1200 ha of rhizoma peanut (RP) had been planted in Florida (Niles et al., 1990), with plantings increasing to 8100 ha by 1999 (E. C. French, personal communication). The plant is being tried in other Deep South states as well (Prine et al., 1986; Ocumpaugh, 1990; Mooso et al., 1995). Factors slowing its use by producers include farmer unfamiliarity with the crop and high establishment costs (Prine et al., 1986).

Another reason for RP's limited use may be its slow rate of establishment. In studies by Valentim et al. (1987) and Terrill et al. (1996), RP was slower to establish than alfalfa. In the study by Terrill et al. (1996), RP produced less DM than did alfalfa (cv. 'Pioneer 526') in the first 2 yr (11.9 vs. 6.1 Mg/ha). In the third year of the study, however, DM production did not differ between RP and alfalfa (10.6 vs. 11.4 t/ha), and leaf yield was greater for RP (6.2 vs. 5.4 metric t/ha). Similarly, Valentim et al. (1987) found that RP outyielded alfalfa (cv. 'Florida 77') in the fourth year of their trial. Florida 77 has poor stand longevity, however, and over time this may affect comparison of yield for the two forages.

Despite its establishment and propagation difficulties, RP may still be suitable to the region. The forage has few disease or nematode problems (Prine et al., 1981; Baltensperger et al., 1986), is palatable to a wide range of livestock (French et al., 1987), and is persistent under grazing (Sollenberger et al., 1987).

An array of clipping regimes has been used to study the effects of defoliation on nutritive value of RP. In a two-year study, Beltranena et al. (1981) examined the effects of 2-, 4-, 6-, 8-, 10-, or 12-wk cutting intervals on yield, % CP, and % IVOMD. As clipping interval increased, concentration of CP and IVOMD declined. Crude protein percentage ranged from 21.9 to 14.7% and IVOMD from 74.3 to 64.8%. Saldivar et al. (1990) also found decreases in concentrations of CP and IVOMD with increased interval between clippings. Their results implicated leaf/stem ratio and its rate of change as important factors influencing nutritive value.

Romero et al. (1987) investigated the effects of season and of increasing week of regrowth on nutrient composition and digestibility of RP. They reported greater NDF

and ADF and lower CP concentrations for leaves of RP grown in summer vs. fall. Response to regrowth intervals between leaf and stem fractions was variable, but investigation of combined leaf and stem fractions showed increasing fiber and decreasing CP concentrations with increasing maturity.

The concentration of CP in RP was less than that in alfalfa, while concentrations of neutral and acid detergent fiber were greater (Romero et al., 1987; Terrill et al., 1996). *In situ* experiments showed RP to have slower rates of DM disappearance than alfalfa (Romero et al., 1987) but similar concentrations of highly soluble DM (24 vs. 27%) and less potentially digestible (43 vs. 45%) DM (Romero et al., 1987). Although alfalfa had greater disappearance of CP after 24 h (85 vs. 72%), the authors noted that even with less CP, RP "may potentially contribute more protein post-ruminally than alfalfa" due to its less ruminally soluble and potentially degradable protein.

In the study by Beltranena et al. (1981), yields of DM were 6.6 and 10.0 t/ha at the 4- and 6-wk clipping intervals, respectively. Clipping intervals greater than 6 wk did not increase DM yield. Forage had greater concentrations of CP and IVOMD at 4 wk (20.1 and 72.9%) than at 6 wk (17.9 and 70.4%), and the authors suggested a 4 wk defoliation interval might be a suitable compromise between quantity and nutritive value for intensive grazing systems.

Ortega-S. et al. (1992) studied the effects of different grazing frequencies and intensities by beef heifers on performance of RP pastures. With a 42-d grazing cycle, a stand of 80% RP could be maintained if residual DM was 1700 kg/ha or greater. With a 21-d grazing cycle, the residual DM needed to maintain an 80% stand was 2300 kg/ha. The study underscores the importance of proper grazing management of RP pastures.

Sollenberger et al. (1987) compared performance of stockers grazing either RP or bahiagrass (*Paspalum notatum* Flügge) pastures in a rotational stocking system without supplement. Animals grazing RP had greater ADG than animals grazing bahiagrass (0.98 vs. 0.37 kg/d, respectively). Although bahiagrass pastures supported more animals (4.3 vs. 3.0 head/d) for a greater number of days (157 vs. 119 d), total gain/ha over the growing season was greater for animals grazing RP (316 vs. 232 kg/ha).

Trials with growing goats also indicate that RP is a high quality forage. When fed RP or alfalfa hays, growing goats eating RP always had numerically greater voluntary intake, and significantly greater ($P < 0.07$) intakes for 9 wk of the 20-wk study (Gelaye et al., 1990). Concentrations of NDF (45.3 vs. 45.8%), ADF (34.4 vs. 33.3%), and ADL (8.9 vs. 8.0%) were similar for alfalfa and RP, respectively. Organic matter (**OM**) concentration was 2 percentage units greater for RP. Apparent digestibility of OM and fiber fractions was greater for RP. Goats consuming RP had both greater gain in BW and feed conversion efficiency but less ($P < 0.08$) retained nitrogen and less ruminal propionate concentration. Numerically less N retention, less ($P < 0.09$) ruminal propionate concentration, and greater acetate:propionate ratio were also observed by Gelaye and Amoah (1991).

Gelaye and Amoah (1991) fed growing goats complete diets containing either 10.5% (as-fed basis) ground RP or ground alfalfa hay. Diets containing RP had about 10% more NDF than those containing alfalfa, mostly due to a greater hemicellulose concentration. Feed intake and ADG were numerically less but not significantly different for animals consuming the RP diet. Apparent digestion coefficients for CP, NDF, and

hemicellulose tended to be greater ($P < 0.07$) when goats ate the diet containing RP. Though not stated, this may have been due to slower rate of passage.

Staples et al. (1997) showed that RP silage is suitable for lactating dairy cows. The researchers fed 50:50 forage:concentrate diets, substituting RP for corn silage at 0, 40, 70, and 100% of the forage source (0, 20, 35, and 50% of dietary DM). Milk yield was greatest when cows ate diets with 20% RP silage, following the same pattern as DMI. Linear decreases ($P < 0.10$) of both total VFA concentrations and body weight gain ($P < 0.05$) were observed with increasing RP silage. This likely reflects lesser concentrations of energy in RP silage as compared with corn silage.

Use of RP in grazing systems for lactating dairy cows has not been reported previously. Questions needing research include effects of SR and supplementation rate for animals grazing RP. Economic costs must particularly be considered because "slow establishment, vegetative propagation, and the need for chemical weed control . . . [make] rhizoma peanut…a high-input, management-intensive forage crop . . . [requiring] appropriate attention to all production needs and inputs" (Mooso et al., 1995). Such requirement "costs" may be prohibitive despite its excellent pest resistance and nutritive value characteristics.

Some Management Strategies for the Improvement of Milk Production in Subtropical Environments

Bovine Somatotropin (bST)

Some of the original investigations of the efficacy of exogenous bST were conducted with animals on pasture (Brumby and Hancock, 1955; Brumby, 1956), but the majority of the related literature investigates its effects on the performance of cows in confinement. Further, investigations of the use of bST with pastured cows primarily have

been limited to temperate climates (Brumby, 1956; Peel et al., 1985; Hoogendoorn et al., 1990; Chilliard et al., 1991).

Generally, bST injections increase milk production of cows on pasture. Results from Chilliard et al. (1991) indicated no effect of bST on milk production, but the results were confounded by a greater amount of concentrate feeding to control cows. Treated cows tended to lose more weight, which was attributed to medium quality available pasture and low amounts of concentrate supplementation.

Peel et al. (1985) tested the effects of growth hormone with five pairs of monozygotic twins. One twin from each pair received a daily injection of 50 mg of growth hormone for 22 wk. The animals grazed ryegrass-white clover pastures, and the SR was intentionally kept low so as not to limit the animals' genetic potential. Milk production increased nearly 18% with bST injection (19.8 vs. 23.3 kg of milk/d) but milk composition was unchanged. Pasture intake, measured twice, was numerically greater (8%) at the eighth week of the trial and significantly greater (14%) by the 22nd wk. Feed conversion efficiency and BW were not changed, but the treatment group appeared to have greater body condition loss during the first 4 wk of the trial.

A 10% increase in milk production due to bST was reported by Hoogendoorn et al. (1990). Cows grazed ryegrass-white clover pastures and were injected bi-weekly with a controlled release formulation that delivered 25-mg of bST/d. Milk yields totaled 2360 and 2600 kg/cow for the control and bST-treated cows over the 26-wk trial, with similar increases in milk fat and protein production. Milk yield was greater when pasture was not limiting. A period of warm, dry weather resulted in a decline in herbage production and a concomitant convergence of group milk yields. Differences due to treatment

returned with provision of supplemental greenchop corn and increased pasture herbage. Although the authors were unable to discern measurable differences in DMI, the changes in production with changes in feed supply indicated that cows treated with bST likely had greater intakes.

Intake differences were shown by Michel et al. (1990), who fed cut pasture (ryegrass-white clover) to lactating dairy cows and found significant increases in DMI within 4 wk of treatment with bST. Means of milk response were not reported, but cows of low genetic merit had greater response to bST than did cows of high genetic merit. Little difference in BW was observed over the course of the 50-d trial, but body condition score was generally less for bST treated cows than for controls. This indicates the necessity of providing adequate feed to meet the energy requirements of cows treated with bST.

Valentine et al. (1990) reported that bST injections increased milk production from cows grazing ryegrass-subterranean clover pastures and supplemented with a barley-faba bean (*Vicia faba*) concentrate. Injections of 320 mg of a sustained release formulation every 28, 21, or 14 d resulted in average dosages of 11.4, 15.2, or 22.8 mg/d. Milk production was 17.6, 18.1, and 18.8 kg/d vs. 15.9 kg/d for control cows, corresponding to 10.7, 13.8, and 18.2% increase in milk production with increased dose. Live weights were also increased, and the authors attributed this to greater gut fill due to greater pasture intake, although intake was not measured

Hartnell et al. (1991) explored dose responses within parities with much greater levels of bST administered (biweekly doses of 250, 500, or 750 mg of bST) to cows in confinement in four different geographic regions within the U.S.A. Averaged over

parities, production ranged from 25.2 to 31.5 kg of milk/cow per d, and increases above control were 12.3, 15.9, and 25.3% for the three treatments, respectively.

Effects of Heat on Milk Production, and Cooling Strategies for Pastured Cows

Cool, comfortable cows produce more milk. Milk production and tolerance to heat stress are likely inversely related (Smith and Mathewman, 1986) due to the high rate of metabolism associated with milk synthesis (Marai and Forbes, 1989). Generally, feed intake begins to decline when mean daily environmental temperatures reach 25 to 27°C, though this is modulated by climatic and nutritional factors (Beede et al., 1985; Beede and Collier, 1986). Reductions in DMI occur due to decreased grazing activity, increased water consumption and increased respiration, benefiting the heat-stressed ruminant by reducing heat load via lessened heat of fermentation and gut metabolism (Roman Ponce et al., 1978; Mallonée et al., 1985). Ruminal contraction rates and ingesta passage rates also decrease with elevated temperatures (Attebery and Johnson, 1969; Warren et al., 1974).

Typically, the greater concentration of dietary roughage, the greater the reduction in DMI with elevated ambient temperature (Beede and Collier, 1986). Thus, the negative effects of high ambient temperature on animal production are generally greater for grazing animals because reduction in feed intake is due mainly to reduced forage consumption (Beede and Collier, 1986).

Technologies for heat stress abatement in confined-housing production systems have made great advances in the past decade but are limited for animals on pasture. Typical cooling methods for pasture systems include cooling ponds, fixed or mobile shade structures, trees, and permanent structures such as barns. Immobile structures are

likely less suitable because of the potential for continued camping and concomitant fouling in those areas of prolonged congregation. Increases in pests (flies and other parasites) and infection (primarily mastitis) are possible. Generally, any mechanical methods of cooling such as fans and misters are likely to be difficult to apply to large-scale grazing systems and would be of limited suitability due to increased costs and the potential for fouling the pastures. Some use of shades and misters with mobile irrigation units have been attempted in Florida (J. Trout, personal communication), but no research as to their efficacy has been reported.

Work by Missouri researchers indicates that the pattern of cooling is more beneficial to improving production than provision of cooling in a general sense (Spain and Spiers, 1999; Spiers et al., 1999). Cows had better performance responses when kept at cooler environmental temperatures during the night. Cooling fans were more effective at improving performance when used at night rather than in the daytime. Thus, cows grazing in environments where differences between day and night temperatures are great may not suffer the effects of heat stress as severely as cows in environments with little change between day- and nighttime temperatures.

This cooling opportunity can be diminished, however, if the nighttime relative humidity is high because moist air reduces the efficiency of evaporative cooling (West, 1994). Thus, a more appropriate measure of heat stress would be some combination of temperature and humidity, such as a temperature humidity index (**THI**), as the one referred to by West (1994). The THI is calculated as the dry bulb temperature – (0.55 – 0.55 * relative humidity) * (dry bulb temperature * 58), and mean THI greater than 72 reduce milk production (Johnson, 1987, cited by West, 1994).

bST in Hot Environments

Because of the increase in body temperatures associated with the use of bST, concerns have been raised about its use on heat-stressed cattle (Kronfeld, 1988). In a study by Mollett et al. (1985) milk production was not increased with bST administration, and the authors suggested that a period of high heat and humidity affected the response to treatment.

In a study of bST and shade effects, Zoa-Mboe et al. (1989) reported no increases in milk production due to bST though milk production was increased with shade. However, on a 3.5% fat-corrected basis, both shade and bST treatments increased milk production to approximately 24 kg/d vs. 22 kg/d for control cows. Several positive responses to bST when used in hot climates have been reported across *Bos taurus* breeds, *Bos* species, and ruminant genera (Amiel et al. unpublished data; Ludri et al., 1989; Phipps et al., 1991; West et al., 1990). Generally, provided sufficient quantities of a balanced diet are available, bST is effective in hot conditions.

Amiel et al. (unpublished data) tested the effects of bST in several herds in Jamaica. Milk production responses were similar across a variety of management conditions, increasing approximately 17% with bST (9.9 vs. 11.6 kg of milk/d). Performance responses from eight herds of Jamaican Hope cattle ranged from 16 to 30% whereas 6 and 14% increases were observed for Holstein and Holstein cross cattle injected with bST, respectively. Conditions were hot and humid, pasture forages were generally inadequate due to a period of drought, and extra concentrate typically was not fed to compensate for lack of sufficient pasture.

Johnson et al. (1991) tested the effects of bST in a 30-d farm trial in Florida, and in a 10-d trial with cows in an environmental chamber in Missouri. Injections of bST increased milk production by 21% (28.8 vs. 34.9 kg of 3.5% FCM/d) and 35% (21.0 vs. 28.3 kg of 3.5% FCM/d) for the farm and chamber studies, respectively. While the THI in the farm trial generally remained above 72, and was maintained above 75 in the chamber study, cows appeared capable of dissipating additional heat due to increased production, likely by increased respiration rates. Elvinger et al. (1992) found that cows treated with bST increased milk yield in both cool and hot environments. However, in both environments, the bST treated cows had greater rectal temperatures, contrary to the findings of Johnson et al. (1991).

Though administration of bST may or may not increase rectal temperatures (Mohammed and Johnson, 1985; Zoa-Mboe et al., 1989; Elvinger et al. 1992) it often causes increased respiration rates for cows in hot environments (Mohammed and Johnson, 1985; Staples et al., 1988; Zoa-Mboe et al., et al., 1989). Mohammed and Johnson (1985) and Staples et al. (1988) reported increased respiration rates with no increases in rectal temperature, but increased temperatures were reported by Zoa-Mboe et al. (1989) and West et al. (1990).

During a 10-d injection period in the study by Staples et al. (1988), respiration rates tended ($P = 0.084$) to increase (78.2 vs. 84.1 breaths/min) with bST administration, but body temperatures were not different (39.6 vs. 39.7 °C). Zoa-Mboe et al. (1989) reported increases in respiration rates (107 vs. 113 breaths/min) and rectal temperatures (39.8 vs. 40.0 °C) with bST treatments.

West et al. (1990) indicated that bST is efficacious under hot and humid conditions, for both Jersey and Holstein cows. Milk production increased 21% with bST administration, though the increase was greater for cows at one standard deviation below pretreatment mean milk production. Response to bST for cows one standard deviation above pretreatment mean milk production was non-significant. Both a.m. and p.m. body temperatures were increased in cows administered bST. Treatment by breed interactions were observed for both production and body temperature increases. Compared to Jerseys, Holsteins had greater milk production increases in response to bST but lower body temperature increases. The authors hypothesized that the increased body temperatures partially explain the lower production responses of Jerseys. If this is correct, then increases in temperature with bST cannot be explained solely by increases in metabolism due to increased milk production, an idea supported by the work of Cole and Hansen (1993).

While management strategies such as designed shading and bST improve animal performance, few have investigated their use with lactating dairy cows grazing pasture under hot conditions. More generally, grazing systems management for intensive dairy production in hot climates has received little attention in the United States. While utilization of grazing represents a potentially viable method of production in the Southeast, the limited information for producers regarding recently released forages adapted to the region, as well as responses to various management strategies prompted the research that follows.

CHAPTER 3
PASTURE-BASED DAIRY PRODUCTION SYSTEMS: INFLUENCE OF FORAGE, STOCKING RATE, AND SUPPLEMENTATION RATE ON ANIMAL PERFORMANCE

Introduction

The economics of dairying in the United States has encouraged farmers to search for new ways to reduce costs. While increasing herd size is a common option, many smaller producers have begun using intensive rotational stocking systems to reduce inputs. However, for producers using grazing in the Southeast, the climate presents unique challenges to production. The ability to grow superior quality forages is of particular concern for graziers (producers using grazing systems). Perennial, warm-season forages typically are of lower nutritive value than either cool-season perennials or warm-season annuals, but they do have the agronomic advantage of being adapted to the region. Thus, despite their lower quality, forages such as bahiagrass (*Paspalum notatum*) and bermudagrass (*Cynodon dactylon* (L.) Pers.) are the foundation of forage production systems for grazing animals in the Southeast.

Recent literature regarding grazing dairy systems in the southeastern United States is limited. The majority of data pertaining to dairy cow grazing in North America has been published by researchers in the Northeast and Midwest under very different environmental conditions. Some research from Australia and other tropical areas may be applicable to the southeastern environment, but the forages grown are typically of different genera and the amounts of concentrate fed are less than the amounts provided by

U.S. producers. Thus, our first objective was to investigate animal and pasture productivity when two recently released forages were used as a grazing base for lactating dairy cows.

Supplemental concentrate feeds typically are fed to lactating dairy cattle in the U.S. The availability of inexpensive concentrates makes this possible and desirable, especially since wholly forage-based diets cannot meet the energy requirements of high-producing, lactating dairy cows. However, supplement can have a large effect on DMI and rumen function, and thus production responses to supplement are inconsistent. Providing supplement may not be profitable, and factors such as pasture and animal management should be included when considering the efficacy of supplementation. Thus, our second objective was to test animal and pasture production responses to two rates of supplementation within each forage base.

The response to forage and supplement may depend upon stocking rate. Most models describing the effect of stocking rate on production indicate that while production per animal decreases with increasing stocking rate, production per land area increases. Optimum pasture utilization typically requires stocking rates at which forage consumption is limited, but excessively high stocking rates may limit production per land area if pasture productivity is compromised. With high stocking rates, however, the response to forage type or supplement may be greater than in situations in which forage is not limiting. Because information about the effect of stocking rate and its interactions with forage type and supplement level on the productivity of grazing, lactating dairy cattle was not available, our third objective was to determine animal and pasture

production responses to two stocking rates within each forage-supplementation rate combination

Materials and Methods

Cows, Design, and Treatments

Year one. On 10 July 1995, primiparous (n = 22) and multiparous (n = 22, mean parity = 2.5) Holstein cows (mean DIM = 106 ± 32) at the University of Florida Dairy Research Unit, (29°43' N latitude) were assigned to one of eight management treatments arranged in a 2 X 2 X 2 factorial in two replicates. The main treatment factors were 1) forage species grazed: bermudagrass (*Cynodon dactylon X C. nlemfuensis* cv. 'Tifton 85') (**BG**) or rhizoma peanut (*Arachis glabrata* cv. 'Florigraze') (**RP**), 2) supplementation rate (**SUP**): 0.33 or 0.5 kg of supplement (as-is)/kg of daily milk production, and 3) stocking rate (**SR**): 5 or 7.5 cows/ha for cows grazing BG pastures and 2.5 or 5 cows/ha for cows grazing RP pastures. All cows received 500 mg of sometribove zinc (Posilac®; Monsanto, St. Louis, IL.) subcutaneously every 2 wk.

Each of the three experimental periods were 28 d in duration, with the first 14 d of each period used for adjustment to a newly assigned treatment, and the last 14 d for collection of data. In period 2, storm damage during the adjustment period caused a 10-d delay. During this time, cows were kept on non-experimental pastures of their respective forage assignment for period 2, and all cows were fed supplement at the greater rate. Cows were assigned randomly to treatment for each period with the restriction that no cow received the same treatment more than once, and the number of changes from a given treatment to another treatment was balanced.

Soils were primarily of the Tavares (hyperthermic, uncoated Typic Quartzipsamments) and Chipley (thermic, coated Aquic Quartzipsaments) series with average P, K, and Mg concentrations of 99, 26, and 50 mg/kg, respectively.

Bermudagrass pastures were fertilized with 67 kg of N/ha on 22 May, 30 June, and 1 September. Nitrogen was applied as NH_4NO_3 at the latter dates and as a combination of NH_4NO_3 and $(NH_4)_2SO_4$ on 22 May. All pastures received a total of 33 kg of S/ha on 22 May, with sulfur applied to RP pastures in the form of $CaSO_4$. In addition, all pastures were fertilized with 67 kg of K_2O/ha in May.

In order to stage the forage growth, Holstein heifers (approximately 400 kg of body weight (**BW**)) grazed both forages from 7 June to 1 July 1995. Stocking rates were 10 and 5 heifers/ha for BG and RP pastures, respectively, and animals were fed no supplement. Experimental cows went onto pastures on 6 July, 4 d before the official start of the trial.

Bermudagrass and RP pastures were divided into 22 and 29 paddocks respectively, allowing for 21- and 28-d rest periods between grazing events. Cows were kept in the bounds of individual paddocks with polywire fencing and paddocks were back-fenced. Cows were provided shade structures and water tubs that were moved with the cows to a fresh paddock each morning. Shade structures were 3-m tall, constructed of galvanized metal pipe, stretched with 80 % shade cloth, and designed to provide a minimum of 4.65 m^2 of shade/cow.

Cows walked 0.4 to 1.2 km from pasture to the parlor for milking and back to pastures twice daily. Cows were milked at approximately 0700 and 1800 h. Supplement was a 4:1 mixture (as-fed) of high energy pellets:whole cottonseed (Table 3.1)

TABLE 3.1. Ingredient and chemical composition of supplements fed to lactating Holstein cows on pasture.

Item	Year 1995	Year 1996
Ingredients (% of DM)		
Corn meal	40.2	--
Hominy	--	35.3
Soybean hulls	24.0	23.9
Soybean meal (48%)	7.2	9.6
Whole cottonseed	20.0	19.8
Dried cane molasses	4.0	5.0
Mineral mix[1]	1.0	--
Mineral mix[2]	--	2.5
Calcium carbonate	1.0	1.3
Mono-Dical phosphate	0.4	--
Salt	0.4	--
Trace mineralized salt[3]	--	1.3
Diabond	0.8	--
Sodium bicarbonate	1.0	1.3
Chemical composition		
Dry matter, %	90.4	91.4
Ash, %	9.5	7.5
NEL, Mcal/kg of DM[4]	1.90	1.89
NDF, % of DM	32.6	42.5
ADF, % of DM	23.3	27.7
CP, % of DM	15.6	18.0
Ca, % of DM	1.16	0.91
P, % of DM	0.43	0.61
Mg, % of DM	0.34	0.34
K, % of DM	1.13	1.33
Na, % of DM	0.64	0.93
S, % of DM	0.19	0.20
Cl, % of DM	0.26	0.82
Fe, ppm, of DM	537	355
Zn, ppm, of DM	121	159
Cu, ppm, of DM	29.8	33
Mn, ppm, of DM	65.4	66

[1]Composition: > 55% Dyna-Mate, > 0.7% 1% Se, > 0.4% $CoSO_4$, > 1.9% $CuSO_4$, > 2.6% $ZnSO_4$, 0.7% $MnSO_4$, 36.9% MgO, > 0.001% CaI, 1200 IU/g of vitamin A, > 700 IU/g of vitamin D_3, > 300 IU/g of vitamin E.

[2]Composition: 3.8% N, 10.5% Ca, 3% P, 4.5% K, 2% Mg, 7.4% Na, 1.1% S, 5.4% Cl, 1525 ppm Mn, 1750 ppm Fe, 425 ppm Cu, 1500 ppm Zn, 12.8 ppm I, 49 ppm Co, 24.2 IU of vitamin A/g, 35.2 IU of vitamin D/g, and 0.88 IU of vitamin E/g.

[3]Composition (g/100 g): NaCl, 92 to 97; Mn, > 0.25; Fe, > 0.2; Cu, > 0.033; I, > 0.007; Zn, > 0.005; Co, > 0.0025.

[4]Calculated using 1989 NRC values for whole cottonseed.

Cows were divided into their respective SUP treatment groups (n = 2) post milking and fed on a concrete feedbunk line. Amount of supplement offered was based on the average milk production for each group, with feed amounts adjusted twice weekly. This method of feeding potentially confounded the effects of SUP with effects of SR and forage treatments but was considered a typical management practice of commercial farms.

Year two. Holstein cows (n = 62) were evenly divided between one and > 1 parity. Mean parity for multiparous cows was 3.1 lactations and mean DIM for all cows was 126 ± 38.

Experimental design and choice of treatments were as in Year 1. However, based on results from 1995, some modifications to protocol were implemented. Cows were not treated with Posilac®. In 1995 pastures were deemed underutilized, so stocking rate treatments were increased to 7.5 and 10 cows/ha for BG and 5 and 7.5 cows/ha for RP pastures. During Year 2, NH_4NO_3 fertilizer was applied more frequently to BG pastures, but the total quantity applied was slightly less than in 1995. Bermudagrass pastures received 45 kg of N/ha as NH_4NO_3 on 21 May, 8 June, and 7 August. A fourth application of 56 kg of N/ha occurred on 11 September. Potassium was applied at 40 kg of K_2O/ha on 7 June. Pastures were irrigated from 15 May to 12 June at a rate of 25 mm/wk for a total of 100 mm of water. Due to the loss of BG stand, one replicate pasture assigned the low SR and low SUP treatments was removed from the study. Pastures were staged with animals as previously described from 10 June to 6 July. The trial was from 9 July through 2 October 1996.

Cows were milked at approximately 0600 and 1800 h. An unpelleted supplement (Table 3.1) was fed after each milking in troughs located in each paddock. The amount of supplement fed was recalculated twice weekly. Feed troughs were moved with the shade and water tubs each day.

Experimental Procedures

Animal measures. Milk weights were recorded at each milking. Milk samples were collected at six consecutive milkings during each of the last 2 wk of each period. Samples were analyzed by Southeast Dairy Labs (McDonough, GA) for fat and protein concentrations and somatic cell count (**SCC**). Samples were analyzed for milk urea nitrogen (**MUN**) in 1996.

Cows were weighed on three consecutive days at the initiation of the trial and at the end of each period. Body weights were recorded after the a.m. milking and prior to feeding of supplement. Body condition scores (**BCS**) were recorded on one of the weigh days within each period (Wildman et al., 1982).

Respiration rates were recorded on 1 d of each period. Movement of the flank or bobbing of the head was monitored over 1-min intervals. Measures took place while cows were on pasture during the time of greatest potential ambient temperature (approximately 1400 to 1600 h). In 1996, rectal temperatures were measured with small, digital thermometers (Medline™, Medline Industries, Inc., Mundelein, IL) after the p.m. milking.

Blood was obtained from the coccygeal vessels on d 27 of periods 1 and 2 and d 19 in period 3 in 1995. Samples were collected on d 22 or 23 of each period in 1996. Samples were collected into 9 ml Na-heparinized syringes (Luer Monovette,® LH,

Sarstedt, Inc., Newton, NC) after the p.m. milking and placed on ice. Blood was centrifuged (2000 x g for 30 min) and plasma was collected and frozen at –20 °C on the same day. Plasma from 1995 was analyzed for urea N (**PUN**) and glucose at the USDA/ARS Subtropical Agriculture Research Station (Brooksville, FL) following the procedures of Marsh et al. (1965) and Gochman and Schmitz (1972), respectively. In 1996, PUN was determined by kit (Kit 535-A, Sigma®, St. Louis, MO) and read on a plate reader at 540 nm.

Chromium-mordanted fiber was used as an inert marker to determine organic matter intake (**OMI**). Each period, forage was collected across all pastures and composited for each species. Efforts were made to gather forage of quality similar to that consumed. Forages were dried at 55 °C and ground with a stainless steel Thomas-Wiley Laboratory Mill (Thomas Scientific™, Philadelphia, PA) using a 2-mm screen. Fiber from the forage was chromium mordanted according to the method of Udén et al. (1980). The dried, ground forages (approximately 100 g/L H_2O) were boiled approximately 2 h in a mixture of water and liquid laundry detergent (approximately 50 mL). After boiling, the fibers were washed repeatedly with tap water to remove all soap, rinsed with acetone, dried at 105 °C, and weighed. The dried forage (500 to 700 g) was placed in a metal container, and sodium dichromate (100 to 140 g) dissolved in four volumes (approximately 4 L) of water was added to the forage. Addition of Cr (as sodium dichromate) equaled 7% of the fiber DM. This slurry was sealed with aluminum foil and heated in a forced-air drying oven at 105 °C for 24 h. The liquid was then poured off and the fiber was gently rinsed with tap water to remove excess and unbound Cr. Ascorbic acid (Aldrich®, Milwaukee, WI) at half the dry fiber weight was mixed with water, added

to the fiber, and allowed to stand for 1 to 1.5 h. The fiber was rinsed thoroughly with tap water and dried at 105 °C. Three ± 0.02 g (air dry) of mordanted fiber were weighed into 28-g gelatin capsules (Jorgenson Laboratories, Loveland, CO). Across the three periods, average Cr concentration was 42,000 and 46,000 ppm (OM basis) for BG fiber, and 51,000 and 53,000 ppm for RP fiber for 1995 and 1996, respectively.

In all periods of both years, 32 cows were orally-dosed with nine gelatin capsules containing Cr-mordanted fiber (27 g, as-fed) from their respective forage assignments. Capsules were administered with a multiple dose balling gun (NASCO, Ft. Atkinson, WI). In 1995, average dosing time was 1130 h on d 23 of each period. Fecal samples were collected at approximately 0, 7.5, 19.5, 23, 27, 31, 44.5, 55.5, 68.5, 79.5, 92.5, and 103.5 h post-dosing. Samples at 23, 27, and 31 h post-dosing were collected on pasture at the cows' leisure, while the remainder were grab samples taken in holding pens at the milking parlor.

In 1996, cows were dosed after the evening milking on d 25, and fecal samples were collected at approximately 0, 12, 15, 18, 21, 24, 27, 36, 42, 48, 60, 72, and 84 h post-dosing. Collections were made on pasture at h 15, 18, 21, 27, and 42.

Fecal samples were refrigerated or frozen immediately after collection. In 1995, samples from period 1 were dried at 55 °C and samples from periods 2 and 3 were freeze-dried. In 1996, all samples were dried at 55 °C for at least 48 h. All fecal samples were ground through a 1-mm screen with a Wiley mill. Samples (2 g, as-is) were dried at 105 °C and ashed at 550 °C for determination of DM and OM according to AOAC (1990) procedures. Ash was digested in a solution of H_2PO_4 (with added $MnSO_4$) and $KBrO_3$ using heat on a hot plate and analyzed for Cr by atomic absorption spectrophotometry

(Atomic Absorption Spectrophotometer 5000, Perkin Elmer, Norwalk, Conn.) following the methods of Williams et al. (1962). For calculating DM intake, results from the fecal sample analysis were evaluated with PROC NLIN following the method described by Pond et al. (1987; Appendix 1). The parameters generated by this program then were used to estimate fecal output for each cow.

To calculate the intake of pasture, the following assumptions were made:

1) intake of supplement was the same for all cows within a pasture replicate,
2) digestibility of supplement OM was equivalent to calculated TDN from NRC (1989), and
3) digestibility of forage was affected by the level of supplement intake, as determined by the equation of Moore et al. (1999; Appendix 2).

The measure of forage *in vitro* organic matter digestibility (**IVOMD**) for each paddock was used to calculate forage intake by cows grazing that paddock (Pond et al., 1987). Fecal output (kg/d) should equal total intake (kg/d) multiplied by the indigestible fraction of a feed. Thus, estimates of fecal output are dependent upon accurate determination of diet digestibility.

The fecal output observed based on the mordanted-fiber methodology did not equal the fecal output predicted based on estimated forage and supplement digestibilities. For this reason, an iterative SAS (1991) program (developed by J. E. Moore) was employed to adjust the forage intake until the difference between fecal output observed and fecal output predicted differed by less than 0.01 kg/d (Appendix 2).

Expected diet digestibility (% of OM) = [(forage intake, kg of OM * forage digestibility, %) + (supplement intake, kg of OM* supplement digestibility, %)]/total

intake, kg of OM. Because feeding concentrate supplements often alters forage digestibility (Arriaga-Jordan and Holmes, 1986; Berzaghi et al., 1996), the iterative program also employed the equation of Moore et al. (1999; Appendix 2) to adjust total diet digestibility.

Pasture measures. A double sampling technique was used to quantify pre- and post-graze forage mass (Meijs et al., 1982). Every 2 wk of each period, 25 measures of forage height were taken using a 0.25-m^2, aluminum disk meter. Pre-graze measures were recorded in paddocks to be grazed the following d, and post-graze measures were made 1 or 2 d after the cows had grazed the paddock. At one sampling event in each period, two or three samples were collected pre- and post-graze from one paddock per pasture to establish a relationship between herbage mass (**HM**) and the recorded disk heights. After dropping the plate of the disk meter on the forage, a metal ring was used to mark the outline of the disk meter, and the forage within the ring was clipped at ground level. The forage was dried at 55 °C for a minimum of 48 h to a constant weight.

Equations to predict pre- and post-graze forage mass were calculated by regressing mass on disk height measured at double sampling sites. Regression equations were assessed for the following data: all samples within a forage species, all pre- or all post-graze samples within a forage, and pre- or post-graze samples within a period and within a forage. After review of the data, HM equations for both years were derived from pre- and post-graze measurements within periods within a forage.

Feed sampling. Once per period, forage was collected for characterization of chemical composition and digestibility. Attempts were made to collect forage of quality similar to that consumed after first inspecting an adjacent, grazed paddock. Twenty to 30

grab samples were taken from the next paddock to be grazed in each pasture, dried at least 48 h at 55 °C, and ground through a 1-mm screen with a stainless steel Thomas-Wiley Laboratory mill. Samples were analyzed by the University of Florida Forage Evaluation Support Laboratory, Gainesville. For determination of organic matter (**OM**), dried samples were ashed for at least 4 h at 500°C. The modified aluminum block procedure of Gallaher et al. (1975) was used to digest samples prior to analysis for N by the method of Hambleton (1977). Crude protein (**CP**) was then calculated as N * 6.25. Determination of neutral detergent fiber (**NDF**) and IVOMD concentrations were made using the procedures of Golding et al. (1985) and Moore and Mott (1974), respectively.

A single pelleted supplement sample and no whole cottonseed samples were collected in 1995. In 1996, supplement (including whole cottonseed) samples were collected three times in each period. Equal amounts of sample within periods were composited, ground through a 1-mm screen, and submitted to the DHIA Forage Testing Laboratory (Ithaca, NY) for analysis.

Statistical Analysis

Animals. Two cows from the 1995 trial were used in 1996 but were treated as different animals for purpose of analysis. Data were analyzed using the GLM procedure of SAS (1991) with the following model:

$$
\begin{aligned}
Y_{ijklmnop} = {} & \mu + \tau_i + \rho_j + (\tau\rho)_{ij} + \kappa(\tau\rho)_{k(ij)} + \\
& \alpha_l + \beta_m + (\alpha\beta)_{lm} + \gamma_n + (\alpha\gamma)_{ln} + (\beta\gamma)_{mn} + (\alpha\beta\gamma)_{lmn} + \\
& (\rho\alpha)_{jl} + (\rho\beta)_{jm} + (\rho\alpha\beta)_{jlm} + (\rho\gamma)_{jn} + (\rho\alpha\gamma)_{jln} + (\rho\beta\gamma)_{jmn} + (\rho\alpha\beta\gamma)_{jlmn} + \\
& (\tau\alpha)_{il} + (\tau\beta)_{im} + (\tau\alpha\beta)_{ilm} + (\tau\gamma)_{in} + (\tau\alpha\gamma)_{iln} + (\tau\beta\gamma)_{imn} + (\tau\alpha\beta\gamma)_{ilmn} + \\
& (\tau\rho\alpha)_{il} + (\tau\rho\beta)_{im} + (\tau\rho\alpha\beta)_{ilm} + (\tau\rho\gamma)_{in} + (\tau\rho\alpha\gamma)_{iln} + (\tau\rho\beta\gamma)_{imn} +
\end{aligned}
$$

$(\tau\rho\alpha\beta\gamma)_{ilmn}$ +

ν_o +

$\delta_p(\alpha\beta\gamma)_{lmn}$ +

$\epsilon_{ijklmnop}$,

where

μ	= overall mean
τ_i	= effect of year
ρ_j	= effect of parity
$\kappa(\tau\rho)_{k(ij)}$	= effect of cow within year and within parity
α_l	= effect of forage
β_m	= effect of SUP
γ_n	= effect of SR
ν_o	= effect of period
δ_p	= effect of pasture replicate within forage, SUP and SR treatments
$\epsilon_{ijklmnop}$	= effect of residual error.

Single degree of freedom orthogonal contrasts were made to test for treatment effects. Treatments were considered different at P levels < 0.05 and trends are reported for P < 0.10. Cow, parity, and their interactions were removed from the model for the analysis of herbage data.

Results and Discussion

Forage Composition

Averaged across all pastures within forage treatments, estimates of digestibility and nutritive value of RP were greater than for BG (Table 3.2). The RP pastures

TABLE 3.2. Nutritive value characteristics, chemical composition, and calculated net energy of lactation (NE_L) and total digestible nutrients (TDN) of Tifton 85 bermudagrass and Florigraze rhizoma peanut pastures. Samples were hand-plucked once each period, based on visual appraisal of forage consumed by grazing cows.

	Bermudagrass		Rhizoma peanut	
	Year			
Item	1995	1996	1995	1996
CP, % of DM[1]	13.5	13.1	19.0	16.6
ADF, % of DM	45.5	36.5	32.7	32.5
NDF, % of DM [1]	81.9	80.4	43.5	45.5
IVOMD[1,2], % of OM	55.5	62.1	71.2	71.2
TDN[3], %	55.2	58.2	62.1	62.1
NE_L[4], Mcal/kg of DM	1.23	1.31	1.41	1.41
Ash, % of DM	5.64	5.13	8.67	8.48
Ca, % of DM	0.41	0.42	1.64	1.70
P, % of DM	0.33	0.27	0.27	0.26
Mg, % of DM	0.24	0.25	0.39	0.45
K, % of DM	1.97	1.77	1.71	1.58
Na, % of DM	0.018	0.045	0.004	0.008
S, % of DM	0.30	0.24	0.16	0.15
Cl, % of DM	0.57	0.43	0.46	0.41
Fe, ppm of DM	51	65	32	42
Zn, ppm of DM	44.5	43	42	37
Cu , ppm of DM	5	4	3.5	2
Mn, ppm of DM	49	101	47	25
Mo, ppm of DM	1.2	1.4	1.2	1.3

[1]Least squares mean from two samples within each treatment combination collected over three periods within each experimental year.
[2]In vitro organic matter digestibility
[3]Calculated using the equation % TDN = [(%IVOMD*0.49) + 32.2]*OM concentration (J. E. Moore, personal communication).
[4]Calculated using NRC (1989) equations: NEL = [0.0245 * TDN(% of DM) - 0.12].

averaged 4.5 percentage units more CP (17.8 vs. 13.3 %) and contained less NDF (44.5 vs. 81.2%) and ADF (32.6 vs. 41.0%) on a DM basis. Rhizoma peanut had greater average IVOMD (71.2 vs. 58.8%) also. These estimates of nutritive value are similar to values reported by others (Beltranena et al., 1981; Gelaye et al., 1990; Hill et al., 1993; Mandebvu et al., 1998).

Milk Production and Composition Per Cow

Parity and year effects. No main effects of parity were observed, and year effects occurred only for SCC. In 1995, milk contained fewer ($P < 0.001$) somatic cells (286 vs. 596 thousands of cells).

Forage effects. Cows grazing RP pastures produced more ($P < 0.001$) milk than cows grazing BG (17.3 vs. 16.2 kg/d), but milk was of lower fat concentration ($P < 0.01$; 3.42 vs. 3.54 %; Table 3.3). Milk fat production is stimulated by more fibrous diets, and the differences in fiber concentration between the two forages likely explains the difference in milk fat concentration. Greater milk production by cows grazing RP pastures offset the reduced milk fat concentration, as shown by the greater ($P < 0.01$) production of 4% FCM (15.7 vs. 15.0 kg/d) and greater ($P < 0.05$) amount of milk fat produced (0.58 vs. 0.56 kg/d) by cows eating RP. Forage type had no effect on milk protein percent, but greater ($P < 0.001$) quantities of milk protein were produced by cows grazing RP (0.52 vs. 0.48 kg/d). Measured only in 1996, MUN concentrations tended ($P < 0.052$) to be greater when cows grazed RP (17.7 vs. 17.1 mg%). Compared with multiparous cows, primiparous cows had greater SCC when grazing RP (500 vs. 350 thousands of somatic cells) but lower SCC when grazing BG (420 vs. 480 thousands of somatic cells; parity by forage interaction, $P < 0.01$).

TABLE 3.3. Effect of forage, stocking rate (SR), and supplementation rate (SUP) on milk production and composition of Holstein cows grazing Tifton 85 bermudagrass and Florigraze rhizoma peanut during the summers of 1995 and 1996.

	Tifton 85 bermudagrass				Florigraze rhizoma peanut											
	Stocking Rate[1]				Stocking Rate[2]					Probability[3]						
	High		Low		High		Low									
	Supplementation rate (kg, as-fed/kg of milk per d)															
Item	0.5:1	0.33:1	0.5:1	0.33:1	0.5:1	0.33:1	0.5:1	0.33:1	SEM	Forage	SR	SUP	Forage x SR	Forage x SUP	SR x SUP	Forage x SR x SUP
Milk, kg/d	17.9	14.9	17.4	14.6	18.1	16.6	18.2	16.7	0.3	***	NS	***	NS	*	NS	NS
FCM, kg/d	16.3	13.9	16.0	13.7	16.1	15.1	16.2	15.3	0.3	**	NS	***	NS	**	NS	NS
Fat, %	3.44	3.6	3.48	3.6	3.38	3.4	3.3	3.50	0.0	**	NS	***	NS	NS	NS	NS
Fat, kg/d	0.61	0.5	0.60	0.5	0.59	0.5	0.6	0.58	0.0	*	NS	***	NS	***	NS	NS
Protein, %	2.99	2.9	3.01	2.9	3.01	2.9	3.0	2.98	0.0	NS	†	**	NS	NS	NS	NS
Protein, kg/d	0.53	0.4	0.52	0.4	0.54	0.4	0.5	0.49	0.0	***	NS	***	NS	†	NS	NS
SCC[4]	375	530	447	490	374	413	478	423	41	NS	NS	NS	NS	NS	NS	NS
MUN[5], mg %	17.2	18.2	16.0	17.0	17.0	18.8	17.0	18.2	0.4	†	*	**	NS	NS	NS	NS

[1]High and low stocking rates for Tifton 85 bermudagrass were 7.5 and 5.0 cows/ ha in 1995 and 10.0 and 7.5 cows/ha in 1996.
[2]High and low stocking rates for Florigraze rhizoma peanut were 5.0 and 2.5 cows/ ha in 1995 and 7.5 and 5.0 cows/ha in 1996.
[3]$P < 0.001$, 0.01, 0.05, and 0.10 represented by ***, **, * and †, respectively.
[4]Somatic cell count, x1000.
[5]Milk urea nitrogen.

Interactions of forage and year with respect to milk production, 4% FCM production, milk fat percentage, and milk fat production (Figure 3.1) reveal greater reductions in performance in 1996 for animals grazing BG. For cows grazing RP pastures, the 0.26 percentage-unit increase in milk fat concentration from 1995 to 1996 offset the 1-kg decrease in daily milk production. This resulted in the same amount of 4% FCM production over the two years. A smaller increase in milk fat percentage did not offset the decreased milk production in 1996 for cows grazing BG, however.

Stocking rate effects. Stocking rate did not influence milk production, but cows grazing at lower SR tended ($P < 0.053$) to produce milk with greater concentrations of protein (3.00 vs. 2.97%). These responses may be indicative of greater concentrations of degradable protein and digestible OM in the diet and may reflect opportunity to select plant parts of greater nutritive value. Likewise, MUN was lower ($P < 0.05$) when cows were stocked at the lower rate (17.1 vs. 17.8 mg %) suggesting more efficient use of dietary CP for milk protein.

In 1995, greater SR resulted in greater milk and 4% FCM production for cows grazing RP but reduced milk and 4% FCM production for cows grazing BG. Results for 1996 were opposite, with the greater SR causing decreased milk and 4% FCM production for cows grazing RP but increased production for cows grazing BG (year by forage by SR interaction, $P < 0.05$; Figure 3.2). Based on the visual appraisal of the BG pastures at the high SR in 1996 (10 cows/ha), herbage allowance and forage nutritive value were near optimum. Intake of digestible OM may have been greater and thus stimulated milk production. However the RP pastures at the high SR in 1996 (7.5 cows/ha) appeared to lack sufficient high quality forage which likely resulted in a reduction in milk production.

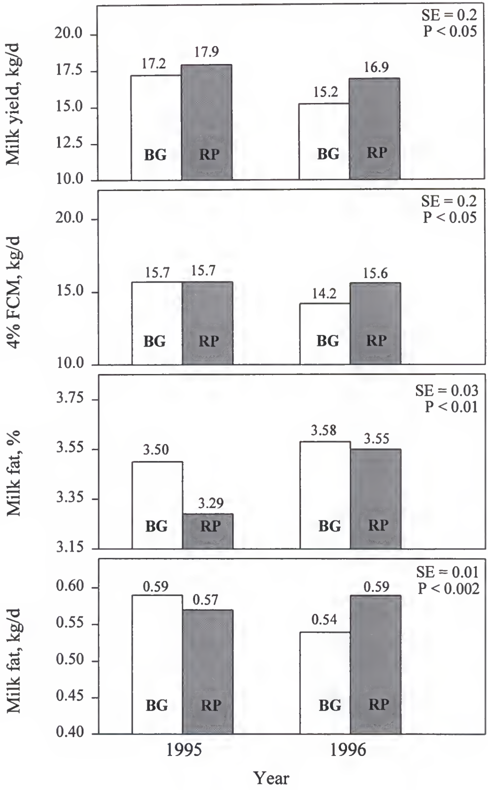

Figure 3.1. Interaction of forage [Tifton 85 bermudagrass (BG) or Florigraze rhizoma peanut (RP)] and year (1995 or 1996) on production of milk, 4% fat corrected milk (FCM), and milk fat and milk fat percent.

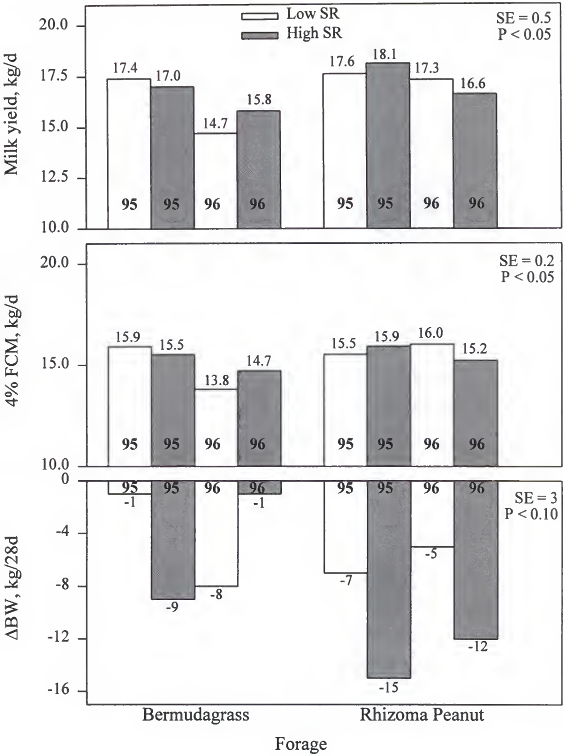

Figure 3.2. Interaction of forage, stocking rate (SR), and year on milk and 4% fat corrected milk (FCM) yields and body weight change (ΔBW). Forages were Tifton 85 bermudagrass and Florigraze rhizoma peanut. Low and high SR for BG were 5.0 and 7.5 cows/ha in 1995 and 7.5 and 10.0 cows/ha in 1996. Low and high SR for RP were 2.5 and 5.0 cows/ha in 1995 and 5.0 and 7.5 cows/ha in 1996.

Supplementation rate effects. Supplementation rate affected all milk production and milk component responses except SCC. Cows receiving the greater SUP produced 2.1 kg/d more ($P < 0.001$) milk and 1.6 kg/d more ($P < 0.001$) 4% FCM. The smaller FCM response to SUP was due to reduced ($P < 0.001$) milk fat concentration (3.41 vs. 3.55 %) with increased SUP. Diets with additional supplement were likely more glucogenic. Greater milk production in response to increased SUP outweighed the decline in milk fat concentration, thus total fat production was greater ($P < 0.001$) by cows fed the greater amount of supplement (0.59 vs. 0.54 kg/d). Supplement likely increased growth of ruminal microbes as was shown by others (Rooke et al., 1987; Berzaghi et al., 1996). This would explain the increased ($P < 0.01$) milk protein percentage with the greater SUP (3.01 vs. 2.96%), resulting in greater ($P < 0.001$) daily milk protein production (0.54 vs. 0.46 kg/d). Providing additional supplement also reduced ($P < 0.01$) MUN concentrations (16.8 vs. 18.1 mg%). The MUN data indicate that providing additional supplement resulted in greater ruminal NH_3 capture by rumen bacteria.

When cows grazed BG, the percent increase in milk production in response to additional supplement was double (19.6 vs. 9.0%) that of cows grazing RP pastures (forage by SUP interaction, $P < 0.05$; Figure 3.3). The greater production response with additional supplement for cows grazing BG is indicative of a lower substitution rate with the lower quality forage (Blaxter and Wilson, 1963; Golding et al., 1976b; Arriaga-Jordan and Holmes, 1986). With each additional kg of supplement fed above the low SUP, cows produced an additional 0.87 kg of milk/d if grazing BG vs. an additional 0.43 kg of milk/d if grazing RP.

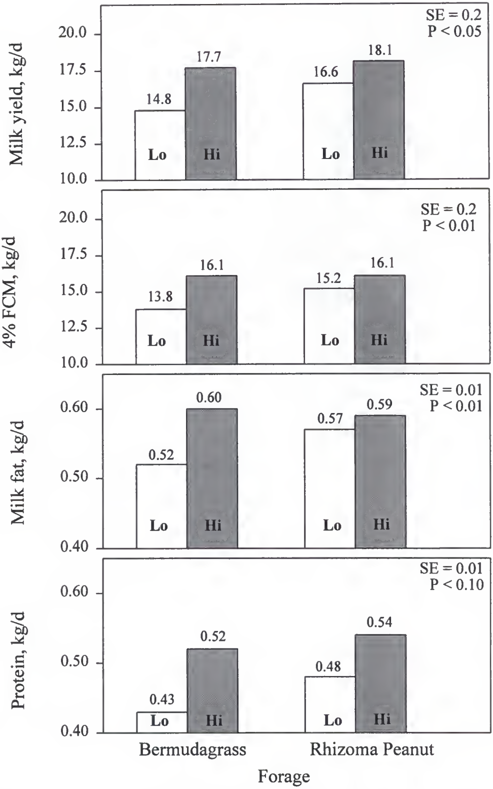

Figure 3.3. Interaction of supplementation rate and forage species on production of milk, 4% fat corrected milk (FCM), milk fat, and protein. Supplementation rates were 0.33 (Lo) and 0.5 (Hi) kg of supplement per kg of daily milk production. Forage species were Tifton 85 bermudagrass and Florigraze rhizoma peanut.

Increasing supplement had similar depressing effects on milk fat percentage across forages. Thus, FCM responses to forage and SUP treatments were similar to that of milk production (forage by SUP interaction, $P < 0.01$; Figure 3.3). For cows grazing BG, the increase in FCM produced with additional supplement (2.3 kg/d) was double the response (0.9 kg/d) of cows grazing RP. Response of daily fat production to SUP followed the same trend (forage by SUP interaction, $P < 0.01$; Figure 3.3). Total protein produced tended to be greater in response to additional supplement when cows grazed BG (forage by SUP interaction, $P < 0.10$; Figure 3.3).

Multiparous cows produced more milk, 4% FCM, and milk fat in response to increased SUP than primiparous cows (parity by SUP interaction, $P < 0.05$). When fed the greater SUP treatment, primiparous cows produced an additional 1.7 kg of milk (18.1 vs. 16.4 kg of milk/d), compared with 2.7 additional kg of milk for multiparous cows (17.7 vs. 15.0 kg/d). Increases of 1.2 and 2.0 kg of 4% FCM due to additional supplement were observed for primiparous and multiparous cows, respectively. Milk fat production within high and low SUP treatments were 0.61 and 0.57 kg/d for primiparous cows compared to 0.59 and 0.52 kg/d for multiparous cows, following the milk production responses to supplement. Milk fat concentrations in response to SUP were not different between parities.

Primiparous cows had lesser SCC when provided additional supplement, compared with greater SCC at the greater SUP rate for multiparous cows (parity by supplement interaction, $P < 0.01$). With the low and high SUP treatments, SCC (in thousands of cells) were 483 and 422 for primiparous cows vs. 360 and 499 for multiparous cows.

Greater 4% FCM ($P < 0.05$) and milk fat production ($P < 0.01$) and greater milk protein concentration ($P < 0.10$) in response to additional supplement were observed in 1996 compared with 1995 (year by SUP interaction; Figure 3.4). Production responses to supplement are greater when forage is limiting (Phillips, 1988) and this would seem a plausible explanation for the increased 4% FCM response to supplement in 1996. However, based on estimates of intake to be presented subsequently, forage intake was not limited by increasing SR in 1996. Opposite the effects of supplement and year on milk protein concentration, the depression in milk fat concentration in response to additional supplement was greater in 1995 than in 1996 (year by SUP interaction, $P < 0.05$; Figure 3.4). That the greatest changes in protein and fat concentrations did not occur in the same year is surprising: milk fat concentrations often decrease with greater supplement feeding with a concomitant increase in milk protein concentrations due to increased microbial growth. Milk protein concentrations essentially did not change due to SUP in 1995 (2.96 and 2.98%) but increased from 2.97 to 3.05% with increasing SUP in 1996. This suggests improved N capture by rumen microbes when cows were fed the greater amount of supplement in 1996.

In 1996, increased supplementation resulted in milk, 4% FCM, and fat production increases between 14 and 20% across parities. In 1995, a similar response was observed for multiparous cows but not for primiparous cows (year by parity by SUP interaction, $P < 0.05$; Figure 3.5). Likewise, milk fat percent was not similarly affected by SUP across parity and years. Reduction in milk fat concentration was similar in 1995 and 1996 for primiparous cows fed the greater SUP. However, milk fat concentration of multiparous cows was more dramatically decreased by greater supplementation in 1995 but was

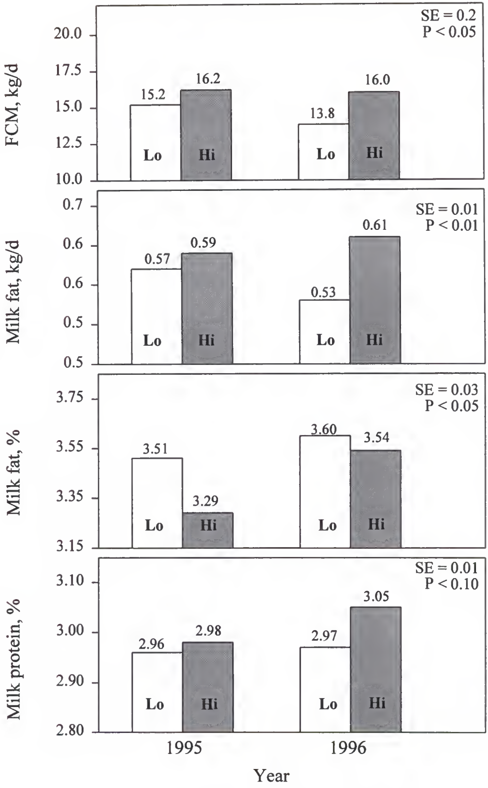

Figure 3.4. Interaction of supplementation rate and year on production of 4% fat corrected milk and milk fat, and percentages of milk fat and protein. Low (Lo) and high (Hi) supplementation rates were 0.33 and 0.5 kg of supplment per 1 kg of daily milk production, respectively.

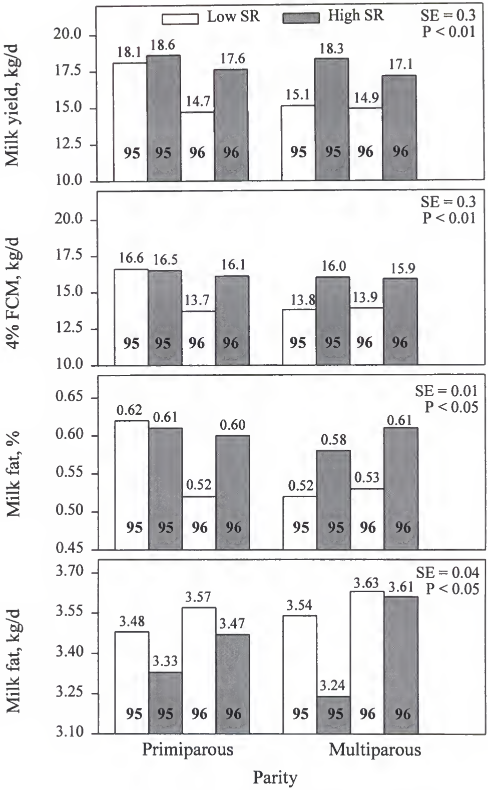

Figure 3.5. Interaction of parity, year, and supplementation rate on production of milk, 4% fat corrected milk (FCM), and milk fat and milk fat percent. Low (Lo) and high (Hi) supplementation rates were 0.33 kg and 0.5 kg of supplement per kg of daily milk production. Supplementation rates did not differ by year (1995 or 1996).

unaffected in 1996 (year by parity by SUP interaction; $P < 0.05$; Figure 3.5). With primiparous cows, milk protein production was less affected by supplementation rate in 1995 than in 1996, while multiparous cows had similar improved responses to supplement in both years (year by parity by SUP interaction, $P < 0.05$). Primiparous cows produced 0.52 and 0.55 kg of protein/d at the low and high SUP in 1995 vs. 0.42 and 0.52 kg of protein/d in 1996. Multiparous cows produced 0.46 and 0.53 kg of milk protein/d in 1995 and 0.43 and 0.51 kg of milk protein/d in 1996 for low and high SUP treatments, respectively.

Milk Production per Land Area

Because production per land area may be a more appropriate measure of profitability for dairies using grazing systems this measure also was calculated. Milk production/cow was multiplied by cow/ha (SR), and the resultant yields per land area were analyzed without cow effects in the model.

The average SR for BG pastures over the 2 years was 7.5 cows/ha vs. 5 cows/ha for RP. As a result milk production from BG far exceeded ($P < 0.001$) production from cows grazing RP (118 vs. 87 kg of milk/ha per day). This represents a nearly forty percent difference in favor of BG.

Stocking rate had a greater effect on milk production/ha than did supplementation rate. Increasing SUP from 0.33 kg of supplement:1 kg of daily milk to 0.5 kg of supplement:1 kg of daily milk increased ($P < 0.001$) milk production 14% on a land area basis (97 vs. 111 kg of milk/ha per d), but increasing SR resulted in a 51% increase ($P < 0.001$) in milk production per land area (83 vs. 125 kg of milk/ha per d).

The response to supplement on a land-area basis was greater when cows grazed BG than RP (132 and 110 kg of milk/ha per day at high and low SUP for BG vs. 90 and 83 kg of milk/ha per day at high and low SUP for RP; forage by supplement interaction, $P < 0.001$). In this case, both the lesser substitution of forage by supplement for cows on BG and the potential to carry more cows on BG pastures overwhelmed RP's greater production per cow.

Production per land area response to increased supplement feeding was greater at the high SR (SUP by SR interaction, $P < 0.01$). Milk production of cows fed the high and low SUP treatments was 135 and 115 kg/ha per day at the greater SR vs. 88 and 78 kg of milk/ha per day with the high and low SUP treatments at the lesser SR. Others (Blaser et al., 1960; Phillips, 1988) have reported a greater response to supplement when forage is limiting, but forage was likely only limiting for RP at the high SR.

Body Weight and Condition

Parity and year effects. Over the two years, multiparous cows weighed an average of 65 kg more ($P < 0.001$) than their primiparous counterparts (537 vs. 472 kg) but had less ($P < 0.01$) body condition (2.49 vs. 2.78). Multiparous cows lost more ($P < 0.05$) weight than did primiparous cows (–9 vs. –6 kg/28-d period), but this difference was not reflected in BCS change. Cow BCS was greater ($P < 0.01$) in 1995 than 1996 (2.78 vs. 2.48), but changes in BCS were less ($P < 0.05$) in 1995 than in 1996 (–0.07 vs. –0.16).

Forage effects. Cows grazing RP lost approximately 5 kg more ($P < 0.05$) BW per 28-d period (–10 vs. –5 kg) than cows grazing BG (Table 3.4). Though the RP was of greater nutritive value and would be expected to support greater weight gain, weight

TABLE 3.4. Effect of forage species, stocking rate (SR), and supplementation rate (SUP) on body weight (BW) and body condition score change (ΔBCS), respiration rate (RR), body temperature (TEMP), and plasma urea nitrogen (PUN) and plasma glucose of Holstein cows grazing Tifton 85 bermudagrass and Florigraze rhizoma peanut during the summers of 1995 and 1996.

	Tifton 85 bermudagrass				Florigraze rhizoma peanut											
	Stocking Rate[1]				Stocking Rate[2]					Probability[3]						
	High		Low		High		Low									
	Supplementation rate (kg, as-fed/kg of milk per d)															
Item	0.5:1	0.33:1	0.5:1	0.33:1	0.5:1	0.33:1	0.5:1	0.33:1	SEM	Forage	SR	SUP	Forage x SR	Forage x SUP	SR x SUP	Forage x SR x SUP
Average BW, kg	507	506	508	507	498	500	504	508	2	*	*	NS	†	NS	NS	NS
ΔBW, kg/28-d period	-6	-4	-4	-5	-16	-11	-9	-4	3	*	†	NS	NS	NS	NS	NS
BCS	2.67	2.68	2.63	2.63	2.60	2.65	2.59	2.61	0.04	NS	NS	NS	NS	NS	NS	NS
ΔBCS/28-d period	0.01	-0.11	-0.20	-0.12	-0.04	-0.10	-0.12	-0.24	0.08	NS	†	NS	NS	NS	NS	NS
RR, breaths/min	93	85	100	89	100	90	102	95	2	*	*	***	NS	NS	NS	NS
TEMP, °C	39.2	39.1	39.2	38.9	39.4	39.3	39.4	39.5	0.1	*	NS	NS	NS	NS	NS	NS
PUN, mg %	13.0	13.4	12.9	12.0	14.9	16.2	14.6	15.3	0.5	***	†	NS	NS	†	NS	NS
Plasma glucose, mg %	59.6	57.4	59.9	57.4	59.9	56.4	59.0	57.6	0.6	NS	NS	***	NS	NS	NS	NS

[1]High and low stocking rates were 7.5 and 5.0 cows/ ha in 1995 and 10.0 and 7.5 cows/ha in 1996.
[2]High and low stocking rates were 5.0 and 2.5 cows/ ha in 1995 and 7.5 and 5.0 cows/ha in 1996.
[3]$P < 0.001$, 0.01, 0.05, and 0.10 represented by ***, **, * and †, respectively.

losses on RP pastures may be attributable to greater energy expenditure associated with greater milk production, or due to less gut fill due to greater intake and faster passage of forage OM, or both.

Stocking rate effects. Cows stocked at the greater SR were slightly lighter, on average, (approximately 4 kg; $P < 0.05$) than cows at the lesser SR. Likewise, BW loss tended ($P < 0.070$) to be greater for cows stocked at the greater rate (–9 vs. –5 kg/28-d period).

Cows assigned to the greater SR lost 7 to 8 kg/28-d period more than cows assigned to the lower SR across years and forages with one exception (Figure 3.2). In 1996, cows grazing BG lost 7 kg less when grazing at the greater vs. lesser SR (year by forage by SR interaction , $P < 0.10$).

Primiparous cows lost 6 to 8 kg of BW/28-d period across forage species and SR except when assigned to BG pastures at the low SR on which BW loss was zero (Figure 3.6). Conversely, the BW loss of multiparous cows was similar (4 to 9 kg of BW/28-d period) except when grazing RP at the high SR, in which multiparous cows lost 19 kg of BW/28-d period (parity by forage by SR interaction, $P < 0.05$).

Supplementation rate effects. Strikingly, SUP had no effect on changes in BCS or BW, nor were SUP by treatment interactions detected. In 1995, the greater SUP resulted in a loss of BW and body condition, likely due to greater milk production, but in 1996, providing additional supplement had little effect on BW and helped maintain body condition (year by SUP interaction, $P < 0.05$; Figure 3.7). The year by SUP interaction patterns for change of BW and BCS are dissimilar in 1996, with the decrease in BCS at

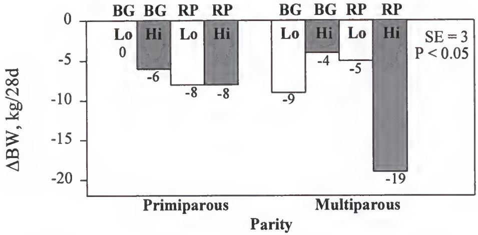

Figure 3.6. Interaction of parity, forage, and stocking rate on body weight change (ΔBW). Average low (Lo) and high (Hi) stocking rates were 6.25 and 8.75 cows/ha for Tifton 85 bermudagrass (BG) and 3.75 and 6.25 cows/ha for Florigraze rhizoma peanut (RP) pastures. Stocking rates were the same across parities.

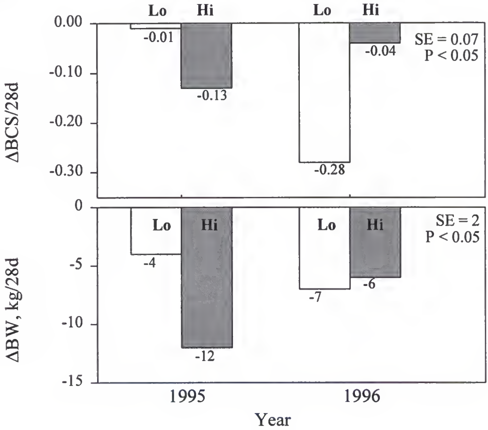

Figure 3.7. Interaction of supplementation rate and year on changes of body condition score (ΔBCS - 5 point scale) and body weight (ΔBW). Low (Lo) and high (Hi) supplementation rates were 0.33 and 0.5 kg of supplement per kg of daily milk production.

the low supplementation rate (-0.28 points) being much greater than would be expected given the change in BW (-7 kg/28-d period).

Cows fed the greater SUP lost more BW than those fed the lesser SUP, regardless of forage, with the exception of cows grazing BG in 1996 which lost the most weight when offered the least amount of supplement (year by forage by SUP interaction, $P < 0.05$; Figure 3.8). Increasing the amount of supplement fed frequently results in greater forage substitution (Davison et al., 1991; Reeves et al., 1996) so that total intake may not change. This may influence BW changes. This effect of grain feeding on forage intake will be discussed subsequently.

A year by SR by SUP interaction ($P < 0.05$) for change of BCS was observed but will not be discussed due to the complexity of explanation given the changes in SR made from Year 1 to Year 2 of the experiment.

Respiration, Temperature, and Blood Metabolites

Parity and year effects. Primiparous cows had greater ($P < 0.001$) concentrations of PUN than multiparous cows (14.8 vs. 13.3 mg %), and the concentration of PUN was greater ($P < 0.001$) in 1996 than 1995 (16.3 vs. 11.8 mg %), reflecting the increased CP concentration of the supplement in 1996.

Respiration rate and temperature were unaffected by parity or year, indicating similar levels of heat stress across years. However, primiparous cows had greater RR in 1995 (99 vs. 92 breaths/min) and similar RR in 1996 (92 vs. 94 breaths/min; parity by year interaction, $P < 0.05$). Glucose in plasma averaged 58.4 mg% and was unaffected by parity or year.

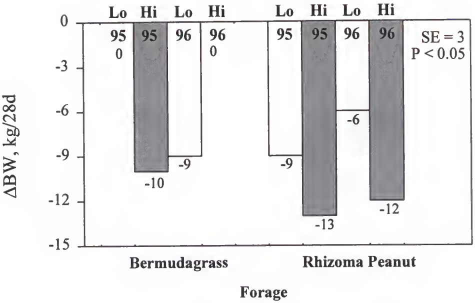

Figure 3.8. Interaction of forage, supplementation rate, and year on body weight change (ΔBW). Forages were Tifton 85 bermudagrass and Florgraze rhizoma peanut. Low (Lo) and high (Hi) supplementation rates were 0.33 and 0.5 kg of supplement per 1 kg of daily milk production. Supplementation rates did not differ by year (1995 or 1996).

Forage effects. Cows grazing RP pastures were more heat stressed, having greater ($P < 0.05$) body temperature (39.4 vs. 39.1°C) and greater ($P < 0.05$) RR (96 vs. 92 breaths/min) than cows grazing BG (Table 3.4). These measures, indicative of greater energy expenditure, agree with the milk production and BW change responses.

Concentrations of PUN were also greater ($P < 0.01$) for cows grazing RP pastures (15.3 vs. 12.8 mg%). Though slight, the increased PUN concentration may represent an additional energetic cost to detoxify ammonia for animals grazing RP.

From 1995 to 1996, PUN concentrations increased approximately 68% (from 9.6 to 16.1 mg%) for cows grazing BG pastures, compared with a 17% increase in PUN concentrations (from 14.1 to 16.5 mg %) for cows grazing RP (year by forage interaction, $P < 0.001$). Plasma urea N concentration reflects dietary CP status (Staples and Thatcher, 1999). The low concentration of PUN for cows grazing BG in 1995 may indicate that dietary protein was limiting for cows grazing BG that year. Therefore, the CP concentration of the supplement was increased in 1996.

Forage had no effect on plasma glucose concentrations. Primiparous cows had greater plasma glucose concentrations than multiparous cows when grazing BG (59.8 vs. 57.8 mg %) but their plasma glucose concentrations were less than those of multiparous cows when RP was consumed (57.4 vs. 58.6 mg %; parity by forage interaction, $P < 0.01$). This interaction likely reflects a greater tendency of increased substitution of supplement for forage for multiparous cows grazing RP. The greater glucose concentrations for primiparous cows grazing BG is less easily explained unless primiparous cows were more aggressive at the feed bunk and more selective at grazing greater quality forage. Little difference was observed in plasma glucose concentrations

between parities or forages in 1996, but large differences in 1995 resulted in a year by parity by forage interaction ($P < 0.01$). This does not follow the milk yield data and may be a reflection of the different methods of feeding between the two years.

Stocking rate effects. Respiration rates were inexplicably greater ($P < 0.05$) for cows stocked at the lower rate (96 vs. 92 breaths/min). Although forage intakes were greater at the lower stocking rate, total intakes were not different between SR, and SR had no effect on body temperatures.

Cows on the lower SR tended to have lower PUN. However, the lower PUN were likely the result of greater supplement OMI for cows on the low SR treatment.

Supplementation rate effects. Supplement rate had no effect on body temperature, but the greater amount of SUP feeding caused a 10% increase ($P < 0.001$) in RR (99 vs. 90 breaths/min). The greater SUP also increased ($P < 0.01$) plasma glucose concentrations (59.5 vs. 57.2 mg%) but did not affect PUN.

While not significant for milk yield, a year by SR by SUP interaction ($P < 0.05$) was observed for plasma glucose. Glucose concentrations followed the pattern of milk yield and reflect the different amounts of supplement fed during the two years.

Glucose concentrations decreased as SUP fed decreased. This occurred to a greater degree with multiparous than primiparous cows in 1995 but to a greater degree with primiparous cows than multiparous cows in 1996 (year by parity by SUP interaction, $P < 0.01$). In 1995, glucose concentrations in plasma at the high and low SUP were 59.7 and 58.7 mg% for primiparous cows vs. 60.8 and 55.9 mg% for multiparous cows. In 1996, plasma glucose concentrations were 59.8 and 56.9 mg% for primiparous cows vs. 58.0 and 57.3 mg% for multiparous cows at the high and low SUP, respectively.

Intake of OM and Nutrients

Parity and year effects. Expressed in terms of daily amount, intake of forage OM, supplement OM, and total OM were not different between parities. It was assumed that cows of all parities ate equal amounts of supplement within a treatment. Therefore supplement OMI as a percentage of BW (**OMIPBW**) was necessarily greater ($P < 0.001$) for the lighter, primiparous cows. Because forage OMI was not different by parity, total OMIPBW also was greater ($P < 0.01$) for primiparous cows as a consequence of our assumptions. Forage, supplement, and total OMI was 1.96, 1.30, and 3.26% of BW/d for primiparous cows compared to 1.79, 1.14, and 2.94% of BW/d for multiparous cows.

Forage effects. Cows grazing RP pastures consumed 49% more ($P < 0.001$) forage OM than cows grazing BG pastures (11.3 vs. 7.6 kg of OM/d; Table 3.5). Cows grazing RP pastures were fed more ($P < 0.01$) supplement because they produced more milk, thus supplement intakes were 6.4 and 5.9 kg of OM/d for RP and BG pastures, respectively ($P < 0.01$). Total OMI were 31% greater ($P < 0.001$) for cows grazing RP in comparison with cows grazing BG pastures (17.7 vs. 13.5 kg/d. The measures of OMIPBW followed the same patterns as OMI. Cows grazing RP pastures consumed more ($P < 0.001$) forage (2.26 vs. 1.51% of BW), more ($P < 0.01$) supplement (1.28 vs. 1.18% of BW) and more ($P < 0.001$) total OM (3.54 vs. 2.70% of BW) than cows grazing BG pastures.

Stocking rate effects. Greater SR reduced ($P < 0.05$) both forage OMI and forage OMIPBW. Cows consumed 9.0 and 9.9 kg of forage OM/d (1.82 and 1.95% of BW), when assigned to the high and low SR, respectively. However, cows stocked at the higher rate consumed slightly more ($P < 0.05$) supplement (6.2 vs. 6.0 kg of OM/d; 1.26

TABLE 3.5. Effect of forage species, stocking rate (SR), and supplementation rate (SUP) on forage, supplement (suppl.) and total organic matter intake (OMI) of Holstein cows grazing Tifton 85 bermudagrass and Florigraze rhizoma peanut during the summers of 1995 and 1996.

	Tifton 85 bermudagrass				Florigraze rhizoma peanut											
	Stocking Rate[1]				Stocking Rate[2]					Probability[3]						
	High		Low		High		Low									
	Supplementation rate (kg, as-fed/kg of milk per d)															
Item	0.5:1	0.33:1	0.5:1	0.33:1	0.5:1	0.33:1	0.5:1	0.33:1	SEM	Forage	SR	SUP	Forage x SR	Forage x SUP	SR x SUP	Forage x SR x SUP
Forage OMI, kg/d	6.7	8.1	7.9	7.7	9.4	11.9	11.4	12.5	0.5	***	*	*	NS	NS	NS	NS
Suppl. OMI, kg/d	7.7	4.1	7.4	4.3	8.4	4.7	7.8	4.5	0.1	***	*	***	NS	NS	†	NS
Total OMI, kg/d	14.4	12.2	15.3	12.0	17.8	16.6	19.2	17.1	0.5	***	NS	***	NS	NS	NS	NS
Forage OMI, % of BW	1.35	1.61	1.57	1.54	1.93	2.42	2.25	2.46	0.11	***	NS	*	NS	NS	NS	NS
Suppl. OMI, % of BW	1.56	0.82	1.48	0.86	1.70	0.95	1.56	0.91	0.03	**	*	***	NS	NS	†	NS
Total OMI, % of BW	2.91	2.43	3.05	2.40	3.63	3.37	3.81	3.37	0.11	***	NS	***	NS	NS	NS	NS

[1]High and low stocking rates were 7.5 and 5.0 cows/ ha in 1995 and 10.0 and 7.5 cows/ha in 1996.
[2]High and low stocking rates were 5.0 and 2.5 cows/ ha in 1995 and 7.5 and 5.0 cows/ha in 1996.
[3]$P < 0.001, 0.01, 0.05$, and 0.10 represented by ***, **, * and †, respectively.

vs. 1.20% of BW). Thus, total OMI and OMIPBW were not different due to SR (15.3 and 15.9 kg of OM/d and 3.08 and 3.16% of BW/d).

At the high SR, primiparous cows ate less BG whereas multiparous cows ate more BG (parity by forage by SR interaction, $P < 0.05$; Figure 3.9). Conversely, SR had little effect on forage consumption when primiparous cows grazed RP but multiparous cows decreased RP OMI more than 2.5 kg/d with increasing SR (13.0 vs. 10.4 kg of OMI/d for low and high SR, respectively). Similar interactions were observed for total OMI as well as forage and total OMIPBW (Figure 3.9).

Supplementation rate effects. Providing additional supplement led to reduced ($P < 0.05$) forage OMI (10.1 vs. 8.8 kg/d for high and low SUP treatments, respectively). Total OMI was 2.2 kg/d greater ($P < 0.001$) for cows on the high SUP treatment (16.7 vs. 14.5 kg/d). Results for OMIPBW followed the same pattern.

Cows grazing RP pastures experienced a greater decrease in forage consumption when fed more supplement compared to those grazing BG pastures. The substitution of forage OM by supplement OM (kg/kg) was 0.51 for RP and 0.18 for BG. Though the forage by SUP interaction was not significant for forage OMI, cows grazing BG pastures and provided greater amounts of supplement increased total OMI by 22 % vs. a 10 % increase in total OMI with additional supplement for cows grazing RP. Greater substitution rates of supplement for forage have been reported for greater quality forages (Golding et al., 1976b). The forage by supplement interaction for milk production (Figure 3.3) further supports the conclusion of greater substitution rates of grain for forage for cows grazing RP because cows were better able to maintain milk production at the low SUP when grazing RP compared with cows grazing BG. Assuming that SR

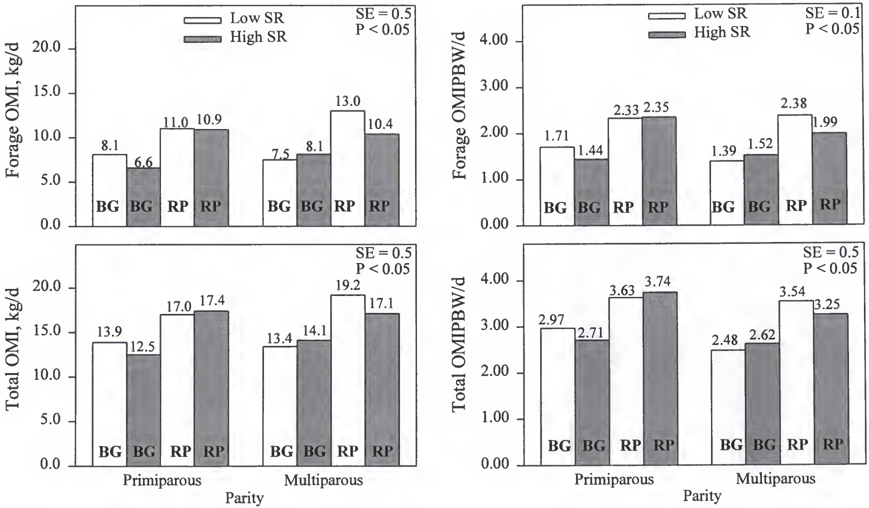

Figure 3.9. Interactions of parity, forage, and stocking rate (SR) on forage and total organic matter intake (OMI) and forage and total OMI as a percent of body weight (OMIPBW). Forages were Tifton 85 bermudagrass (BG) or Florigraze rhizoma peanut (RP). Average low and high SR for BG pastures were 6.25 and 8.75 cows/ha. Average low and high SR for RP pastures were 3.75 and 6.25 cows/ha.

could be increased in proportion to the decrease in forage consumption, and based on average SR across years, SR for BG could be increased from 7.5 to 8.25 cows/ha and SR for RP could be increased from 5.0 to 6.0 cows/ha when feeding the greater amount of supplement.

Year by supplement and parity by supplement interactions ($P < 0.05$) also were observed for supplement OMIPBW. The data have little meaning, however, due to the differences in BW across years and parities (data not shown).

Calculations of nutrient intake within forage and SUP treatment combinations indicated that 4% FCM production likely was not limited by nutritional deficiency with the exception of cows grazing BG and fed low amounts of supplement (Table 3.6). Cows fed the lesser amount of supplement when grazing BG were likely deficient in daily intake of DM, energy, and CP and had marginal intake of Ca and P. With BG managed as in these experiments, large amounts of supplement must be fed or the supplement nutrient concentrations must be adjusted to ensure adequate nutrient intake.

Conversely, supplement intakes were likely excessive for cows grazing RP. With either SUP, cows grazing RP consumed excess CP (Table 3.6) that likely increased maintenance costs due to the need for increased N excretion. Assuming all N in excess of requirement was lost as urea, and using the NRC (1989) estimate of 7 kcal of ME/g of N excreted, N excretion cost cows 1.2 or 1.7 Mcal of ME/d with the low and high SUP treatments, respectively. Only S intake appeared marginal regardless of SUP.

Comparison of our intake data with NRC estimates of nutrient requirements was made as well (Table 3.7). The data represent only cows used in the intake estimate study.

TABLE 3.6. Calculated daily intake of nutrients[1] by cows grazing Tifton 85 bermudagrass (BG) or Florigraze rhizoma peanut (RP) pastures. Cows received supplement (SUP) at either 0.33 kg (Low) or 0.5 kg (High) (as-fed) per kg of daily milk production.

	Ingredient															
	NEL[1]	DM	NDF	ADF	CP	Ca	P	Mg	K	Na	S	Cl	Fe	Zn	Cu	Mn
	Mcal/d	kg/d				g/d							mg/d			
Low SUP																
BG	10.6	8.3	6.7	3.4	1.1	35	25	20	156	3	23	42	481	364	37	624
Supplement	8.8	4.6	1.7	1.2	0.8	48	24	16	57	36	9	25	2058	646	145	303
Total	19.3	12.9	8.5	4.6	1.9	82	49	36	212	39	39	32	2540	1010	182	927
High SUP																
BG	9.8	7.7	6.2	3.2	1.0	32	23	19	144	2	21	38	445	336	35	576
Supplement	15.7	8.2	3.1	2.1	1.4	85	43	28	101	65	16	45	3676	1154	259	541
Total	25.4	15.9	9.3	5.3	2.4	117	66	47	245	67	37	83	4120	1490	293	1118
Low SUP																
RP	18.7	13.3	5.9	4.3	2.4	221	35	56	218	1	21	58	492	524	36	477
Supplement	9.6	5.1	1.9	1.3	0.8	52	26	17	62	40	10	27	2255	708	159	332
Total	28.3	18.3	7.8	5.6	3.2	274	61	73	280	40	31	85	2746	1231	195	810
High SUP																
RP	15.9	11.3	5.0	3.7	2.0	189	30	47	186	1	18	49	419	447	31	407
Supplement	16.9	8.9	3.3	2.3	1.5	92	46	30	109	70	17	48	3970	1246	279	585
Total	32.9	20.2	8.4	6.0	3.5	281	76	78	295	71	35	98	4389	1693	311	992
Requirement[2]	23.3	16.0	4.5	3.4	2.2	84	54	32	144	29	32	40	800	640	160	640

[1]Calculated from the average of estimates presented in Tables 3.1 and 3.2.
[2]Calculations based on NRC requirements for a 500 kg cow producing 20 kg of 4.0% FCM and gaining 0.275 kg/d. Intake was assumed to be 3.2% of BW.

TABLE 3.7. Effect of forage, stocking rate (SR), and supplementation rate (SUP) on bodyweight (BW) change, 4% fat corrected milk (FCM) production, and measures of energy (E) status of Holstein cows grazing Tifton 85 bermudagrass and Florigraze rhizoma peanut during the summers of 1995 and 1996

	Tifton 85 bermudagrass				Florigraze rhizoma peanut					Probability[3]							
	Stocking Rate[1]				Stocking Rate[2]												
	High		Low		High		Low										
	Supplementation rate (kg, as-fed/kg of milk per d)																Forage x SR
Item	0.5:1	0.33:1	0.5:1	0.33:1	0.5:1	0.33:1	0.5:1	0.33:1	SEM	Forage	SR	SUP	Forage x SR	Forage x SUP	SR x SUP	x SUP
Average BW, kg	507	504	508	507	497	500	504	513	3.0	NS	*	NS	NS	NS	NS	NS
FCM, kg/d	16.5	14.2	16.6	13.8	15.8	15.7	16.5	15.5	0.4	†	NS	***	NS	**	NS	NS
Maintenance E, Mcal/d[4]	10.1	10.1	10.1	10.1	10.0	10.0	10.1	10.2	0.3	NS	NS	NS	NS	NS	NS	NS
FCM E, MCal/d[5]	12.2	10.5	12.3	10.2	11.7	11.6	12.2	11.5	0.3	†	NS	***	NS	**	NS	NS
Total E output, Mcal/d[6]	22.4	20.6	22.4	20.3	21.7	21.6	22.3	21.7	0.4	NS	NS	**	NS	*	NS	NS
BW change, kg/d	-0.2	-0.3	-0.1	-0.1	-0.5	-0.3	-0.2	-0.1	0.1	NS	*	NS	NS	NS	NS	NS
Tissue E, Mcal/d[7]	0.9	1.3	0.5	0.6	2.3	1.5	1.1	0.4	0.5	NS	*	NS	NS	NS	NS	NS
Forage E intake, Mcal/d[8]	9.3	10.9	10.9	9.4	14.3	18.2	17.7	19.2	0.8	***	†	*	†	†	*	NS
Suppl. E intake, Mcal/d[9]	14.3	7.7	13.8	8.0	15.7	8.9	14.5	8.4	0.3	**	†	***	†	*	†	NS
Dietary intake E, Mcal/d	23.5	18.6	24.7	17.5	29.9	27.1	32.2	27.7	0.7	***	NS	***	NS	*	†	NS
Total E input, Mcal/d	24.5	19.9	25.2	18.1	32.2	28.6	33.3	28.1	0.8	***	NS	***	NS	NS	NS	NS
E status, Mcal/d[10]	2.1	-0.7	2.7	-2.2	10.6	7.0	11.0	6.4	0.9	***	NS	***	NS	NS	NS	NS

[1]High and low stocking rates for Tifton 85 bermudagrass were 7.5 and 5.0 cows/ ha in 1995 and 10.0 and 7.5 cows/ha in 1996.
[2]High and low stocking rates for Florigraze rhizoma peanut were 5.0 and 2.5 cows/ ha in 1995 and 7.5 and 5.0 cows/ha in 1996.
[3]$P < 0.001, 0.01, 0.05$, and 0.10 represented by ***, **, * and †, respectively.
[4]Calculated using NRC equations for maintenance and activity, maintenance $E = 0.073*BW^{0.75}$. Requirement was also increased 25% for energy of activity and increased an additional 10% above maintenance for primiparous cows.
[5]Calculated using NRC equations, milk energy = 0.74Mcal/kg*FCM, kg/d.
[6]Total E output = Maintenance E + FCM E, Mcal/d.
[7]Calculated using NRC (1989) equations. Tissue E = +4.92 Mcal/kg BW loss and –5.12 Mcal/kg BW gain.
[8]Calculated using the NRC (1989) conversion of TDN to NEL, where NEL = [0.0245*TDN(% of DM)-0.12]. Calculation of TDN was based on the equation for estimation of TDN in warm-season grasses used by the University of Florida Forage Evaluation Support Laboratory (J. E. Moore, personal communication), where % TDN = [(IVOMD, % * 0.49) + 32.2] * OM concentration.
[9]Calculated using estimated supplement digestibility of 86%. TDN was calculated using tabular values, and NEL was calculated from estimated TDN using NRC (1989) equations.
[10]Energy status = Energy input - energy output.

Predicted energy inputs were greater than outputs by an average of 4.8 Mcal/d (23% of estimated energy requirement) and quite variable. The standard deviation of all energy difference estimates was 7.0 Mcal/d, 32.4% above estimated requirements. The results indicate that either energy intake was overestimated or maintenance energy requirements were underestimated, although maintenance energy requirement was increased from 10% to 25%. Estimates of energy status (energy intake minus energy output) for cows grazing RP pastures were particularly poor, especially for cows fed the greater SUP. Energy states were over-estimated ($P < 0.001$) by 8.8 Mcal/d for cows grazing RP, compared with –0.5 Mcal/d for cows grazing BG. The over-estimate ($P < 0.001$) of energy status was 2.5-fold greater with additional supplementation (2.6 vs. 6.6 Mcal/d for low and high SUP rates, respectively). Some of the variability may be attributed to the method of feeding in 1995. When cows were fed at the feedbunk (1995), intakes would likely vary to a greater degree than when cows were fed from troughs in their individual pastures (1996). However, comparison of energy status predictions between years indicated no improvement, and energy status difference was less in 1995 than in 1996.

These data are subject to several sources of error. Overestimates of intake, underestimates of maintenance requirements, and overestimates of diet digestibility (due to predictions of associative effects) all may have limited the accuracy of prediction. Regardless, the differences between energy inputs and outputs suggest that nutrients of RP were poorly utilized, and that different feeding strategies with respect to supplements are likely necessary to optimally utilize RP's better nutritive characteristics.

Treatment Effects on Forage Nutritive Value Estimates

Analysis values in Table 3.8 represent the least squares means of hand-plucked samples from individual pastures, rather than an average across all pastures within a given forage.

Year effects. Of the nutritive value measures, only NDF was unaffected by year. Decreased ($P < 0.001$) CP (16.3 vs. 14.8% for 1995 and 1996, respectively) would suggest that samples containing lesser concentrations of CP likely included more plant stems, dead leaf, or both. This is contradicted, however, by increased ($P < 0.001$) IVOMD (63.3 vs. 66.7%) and the lack of change in forage NDF concentration (62.7 vs. 62.9%) between years.

Forage effects. The IVOMD and CP concentration of RP exceeded ($P < 0.001$) those of BG pastures by 21 and 33%, respectively, while NDF concentrations of RP were approximately 55% less ($P < 0.001$) than those of BG. Concentrations of in vitro digestible OM, CP, and NDF were 71.2, 17.8, and 44.5% for RP and 58.8, 13.3, and 81.8% for BG, agreeing with the findings of others (Beltranena et al., 1981; Hill et al., 1993).

The IVOMD of sampled BG increased from 1995 to 1996 (55.5 vs. 62.1%) which may indicate that the greater SR increased the quality of BG, while the digestibility of sampled RP pastures was unchanged by year (71.2%; year by forage interaction, $P < 0.001$). Concentrations of CP in BG remained essentially unchanged across years (13.5 vs. 13.1% for 1995 and 1996, respectively), while CP in RP sampled decreased from 1995 to 1996 (19.0 vs. 16.6%; year by forage interaction, $P < 0.01$). Concentration of

TABLE 3.8. Effect of forage species, stocking rate (SR), and supplementation rate (SUP) on forage, supplement and crude protein (CP), in vitro organic matter digestibility (IVOMD), and neutral detergent fiber (NDF) concentrations in Tifton 85 bermudagrass and Florigraze rhizoma peanut during the summers of 1995 and 1996. Samples were hand-plucked once each period based on visual appraisal of forage consumed by grazing cows.

	Tifton 85 bermudagrass				Florigraze rhizoma peanut											
	Stocking Rate[1]				Stocking Rate[2]					Probability[3]						
	High		Low		High		Low									
	Supplementation rate (kg, as-fed/kg of milk per d)															
Item	0.5:1	0.33:1	0.5:1	0.33:1	0.5:1	0.33:1	0.5:1	0.33:1	SEM	Forage	SR	SUP	Forage x SR	Forage x SUP	SR x SUP	Forage x SR x SUP
CP, %	14.3	13.1	13.2	12.4	17.7	18.2	17.9	14.5	0.4	***	†	NS	NS	†	NS	NS
IVOMD, %	60.2	58.3	60.0	56.8	70.8	71.4	71.2	71.5	0.9	***	NS	NS	NS	*	NS	NS
NDF, %	80.7	81.6	81.3	81.0	45.8	44.4	44.5	43.4	0.8	***	NS	NS	NS	NS	NS	NS

[1]High and low stocking rates were 7.5 and 5.0 cows/ ha in 1995 and 10.0 and 7.5 cows/ha in 1996.
[2]High and low stocking rates were 5.0 and 2.5 cows/ ha in 1995 and 7.5 and 5.0 cows/ha in 1996.
[3]$P < 0.001$, 0.01, 0.05, and 0.10 represented by ***, **, * and †, respectively.

NDF in BG decreased from 1995 to 1996 (81.9 vs. 80.4%) while that in RP increased (43.5 vs. 45.5%; year by forage interaction, $P < 0.05$).

Stocking rate effects. Increased SR had no effect on IVOMD or concentration of NDF but did tend ($P < 0.10$) to increase CP concentrations (15.3 vs.15.8% for low and high SR, respectively) as evidenced by the tendency ($P < 0.10$) of greater MUN concentrations of cows kept at the greater SR. Year by SR interactions would indicate forage rather than SR effects, and their absence in these data represents the confounding effect of averaging the results over both forages. Although year by forage by SR interactions were not observed for any nutritive value measure, the numeric patterns were consistent with such interactions but masked by large standard error.

Supplementation rate effects. Supplementation rate had no effect on any nutritive value measures. Increasing SUP had little effect on IVOMD of RP pastures (71.0 vs. 71.5% for low and high SUP treatments, respectively) while IVOMD of BG pastures increased with increasing SUP (57.5 vs. 60.1%; forage by SUP interaction, $P < 0.05$). Similarly, greater SUP resulted in no change in CP concentration (17.8%) of RP, whereas CP concentration of BG tended to increase at the greater SUP (12.8 vs. 13.8; forage by SUP interaction, $P < 0.10$).

These results do not imply that increasing SUP improved forage nutritive value, but rather those cows fed more supplement consumed forage of greater nutritive value as well. Forage OMI data (Table 3.6) support this idea, since greater supplement intake decreased forage intake, which would have allowed for greater selection.

Treatment Effects on Herbage Mass, Availability, and Intake Estimates as Determined by Pasture Sampling

Unless stated otherwise, the HM values presented represent the average of the pre- and post-graze HM values. Herbage allowance (**HA**) represents kg of herbage DM/kg of animal BW. Estimates of HA were calculated as 0.5 * (pre-graze + post-graze HM, kg/ha)/(average BW, kg/cow * cows/ha). The DMI estimates (kg/cow) were calculated as [(pre-graze - post-graze HM, kg/ha) * paddock size, ha/paddock]/(cows/paddock).

Coefficients of determination for the regression equations used to estimate HM typically were greater at the initial pre- and post-graze sampling events within both year and forage type (Table 3.9). Initial estimates of HM appeared to have been better with BG, but the relative change in r^2 from one period to another was less with RP. The larger relative change in r^2 from one period to another with BG is indicative of the accumulation of large quantities of herbage in the BG pastures which made difficult accurate HM estimates.

Year effects. The HM and HA of pastures were less ($P < 0.001$) in 1996, reflecting the effects of both the greater SR and greater ($P < 0.001$) DMI observed in that year (Table 3.10). For 1995 and 1996, HM averaged 6250 and 4250 kg of DM/ha, HA averaged and 2.2 and 1.2 kg of DM/kg of BW, and DMI averaged 12.5 and 19.4 kg of DM/cow per d.

Forage effects. Across periods over the 2 yr, pre-graze HM of BG pastures averaged approximately 2600 more ($P < 0.001$) kg of DM/ha than RP pastures (7270 vs. 4650 kg of DM/ha). This difference carried over to post-graze HM (6250 vs. 3650 kg of DM/ha) measures for forages as well.

TABLE 3.9. Regression[1] groupings and regression coefficients for predicting 1995 and 1996 pre- and post-graze herbage mass of Tifton 85 bermudagrass and Florigraze rhizoma peanut pastures.

	Year					
	1995			1996		
	Period			Period		
Item	1	2	3	1	2	3
Bermudagrass regression grouping						
Pregraze estimates						
Measurements, n	16	13	16	13	13	14
Intercept	21.81	51.73	75.70	23.17	124.59	96.24
Slope	6.797	9.902	10.245	8.989	4.972	5.444
r^2	0.896	0.528	0.421	0.784	0.562	0.344
Postgraze estimates						
Measurements, n	14	15	15	14	13	16
Intercept	40.24	77.13	109.37	27.87	83.74	55.28
Slope	5.597	8.053	8.503	7.227	7.449	7.230
r^2	0.937	0.719	0.579	0.646	0.619	0.872
Rhizoma peanut regression grouping						
Pregraze estimates						
Measurements, n	15	16	15	16	16	16
Intercept	32.68	61.80	46.98	1.186	-0.303	8.836
Slope	7.798	7.927	12.506	10.21	12.14	9.75
r^2	0.700	0.495	0.595	0.730	0.722	0.580
Postgraze estimates						
Measurements, n	13	12	14	16	16	16
Intercept	40.08	73.28	72.67	-18.624	-10.517	-8.791
Slope	7.674	7.046	10.547	14.39	15.24	12.31
r^2	0.735	0.675	0.540	0.693	0.776	0.889

[1]Herbage mass = Intercept + Slope * Disk meter height, cm.

TABLE 3.10. Disk meter estimates of the effect of forage species, stocking rate (SR), and supplementation rate (SUP) on forage pre- and post-graze herbage mass (HM), herbage allowance (HA), and dry matter intake (DMI) of grazing, lactating Holstein cows grazing Tifton 85 bermudagrass and Florigraze rhizoma peanut during the summers of 1995 and 1996.

	Tifton 85 bermudagrass				Florigraze rhizoma peanut											
	Stocking Rate[1]				Stocking Rate[2]					Probability[3]						
	High		Low		High		Low									
	Supplementation rate (kg, as-fed/kg of milk per d)															
Item	0.5:1	0.33:1	0.5:1	0.33:1	0.5:1	0.33:1	0.5:1	0.33:1	SEM	Forage	SR	SUP	Forage x SR	Forage x SUP	x SR x SUP	Forage x SR x SUP
Pre-graze HM, kg/ha	7220	6980	7320	7540	4460	4460	4890	4780	110	***	**	NS	NS	NS	NS	NS
Post-graze HM, kg/ha	6290	5960	6460	6310	3380	3120	4140	3960	100	***	***	*	**	NS	NS	NS
Average HM, kg/ha	6760	6470	6890	6920	3920	3790	4510	4370	100	***	***	†	†	NS	NS	NS
HA, kg of forage/kg of BW	1.6	1.5	2.3	2.3	1.1	1.1	2.0	1.9	0.0	***	***	NS	NS	NS	NS	NS
Forage DMI[4], kg/d	12.0	13.0	15.0	22.3	14.3	17.3	16.3	17.7	1.8	NS	*	*	†	NS	NS	NS

[1]High and low stocking rates were 7.5 and 5.0 cows/ ha in 1995 and 10.0 and 7.5 cows/ha in 1996.
[2]High and low stocking rates were 5.0 and 2.5 cows/ ha in 1995 and 7.5 and 5.0 cows/ha in 1996.
[3]P < 0.001, 0.01, 0.05, and 0.10 represented by ***, **, * and †, respectively.
[4]DMI calculated as [(pre-graze - post-graze HM, kg/ha) * paddock size, ha/paddock]/(cows/paddock).

A year by forage interaction ($P < 0.01$) for HM was observed, and as with the nutritive value estimates, the interaction more likely indicates the effect of increased SR from 1995 to 1996 rather than changes in the forages or their growing conditions. Increasing SR from 1995 to 1996 had less effect on BG, decreasing BG HM by 17% (7390 vs. 6130 kg of DM/ha), but the increased SR decreased RP HM by 38% (5120 vs. 3180 kg of DM/ha).

As with HM, HA was greater ($P < 0.001$) for BG than for RP pastures (1.9 vs. 1.5 kg of pasture DM/kg of animal BW) despite the lower SR used with RP. Because the change in HM due to SR was similar across years, increasing the SR from 1995 to 1996 had less effect on HA in 1996 (year by forage interaction, $P < 0.001$). Thus, the ratios of the HA values were a mathematical consequence of, and very nearly reflect the ratios of the low and high SR within years. Effect of forage was not significant with respect to forage DMI. Average estimated DMI across forages was 16.0 kg of DM/cow per d.

Stocking rate effects. Greater SR reduced ($P < 0.01$) pre-graze HM (5780 vs. 6130 kg of DM/ha (Table 3.10). This was likely due to carry-over effects from previous grazing events within each grazing season as reflected in differences in post-graze HM. The difference ($P < 0.001$) between SR treatments for post-graze HM (4690 vs. 5210 kg of DM/ha for greater and lesser SR, respectively) was approximately 65% larger than the difference between SR treatments for pre-graze HM. Post-graze HM for RP pastures decreased by 800 kg of DM/ha as SR increased (4050 vs. 3250 kg of DM/ha) compared with a 260 kg/ha decline in BG pastures (6380 vs. 6120 kg of DM/ha; forage by SR interaction, $P < 0.01$).

Greater SR resulted in decreased ($P< 0.001$) HA by nearly 40% (1.3 vs. 2.1 kg of pasture DM/kg BW). In 1995, HA at the high and low SR were 1.7 and 2.8 kg of DM/kg of BW vs. HA of 1.0 and 1.5 kg of DM/kg of BW in 1996 (year by SR interaction, $P < 0.001$).

Estimates of DMI were less ($P < 0.05$) for cows assigned to the greater SR treatment (14.1 vs. 17.8 kg DMI/d for high and low SR treatments, respectively). Forage DMI for cows grazing RP pastures differed slightly between SR treatments (15.8 and 17.0 kg of DM/cow per d) while forage DMI was markedly less at the high SR when cows grazed BG (12.5 vs. 18.7 kg of DM/cow per; forage by SR interaction, $P < 0.10$).

Supplementation rate effects. No carry-over effects of SUP treatment were observed in pre-graze HM, but post-graze HM was greater ($P < 0.05$) when cows were fed greater amounts of supplement (5060 vs. 4840 kg of DM/ha). The effect of SUP treatment on HA was not significant. Estimated forage DMI decreased ($P < 0.05$) with the greater SUP treatment (14.4 vs. 17.6 kg of DM/cow per d).

Minson and Wilson (1994) suggested that the lower limit of HA which would not limit individual animal performance is 60 g of OM/kg of BW. The smallest HA observed during the study was 0.75 kg of DM/kg of BW, occurring in 1996 in RP pastures stocked at the greater rate with the low SUP. Based on these estimates, HA was not limiting for any treatment. However, taking samples from ground level inflated the HA values, particularly for BG, due to the inclusion of large amounts of dead herbage. The estimate also has limits due to inclusion of standing dead and stemmy herbage which cows avoided grazing. Thus, a more suitable estimate would have been HA adjusted for the proportion of green material in the sward (Piaggio and Prates, 1997).

Intake may be limited when HM in tropical grass-legume pastures is less than 2000 kg/ha (Cowan and O'Grady, 1976). All pre-graze estimates of HM were greater than 2000 kg/ha, but as with HA, the inclusion of large amounts of dead material may limit the value of the estimate, particularly for BG. Also, the post-graze HM of RP pastures combined with high SR and low SUP treatments in 1996 was 1770 kg of DM/ha, suggesting that forage may have been limiting with that treatment.

All intake estimates via disk meter were quite large relative to the estimates of intake using the marker technique. The effect of supplement on the substitution of forage reported earlier was not observed. The use of a disk meter to estimate DMI is thought best limited to situations where pasture swards are uniform.

Simple Economic Assessment of Supplementation

Using only the milk production data, a simple assessment of income per cow or income per land area was performed (Table 3.11). Milk income was calculated as \$0.33/kg of milk, and supplement costs were calculated as \$0.22/kg of supplement. Supplement intake was estimated as one third or one half of milk production, depending upon the supplement treatment. Supplement cost was subtracted from milk production to provide a simple economic assessment of supplementation.

Cows grazing RP returned equal or greater income on a per cow per day basis than cows grazing BG (\$4.13 vs. \$3.85/cow per day) illustrating the higher digestibility and intake potential of RP. This advantage of RP over BG pastures was greatest when the amount of supplement fed was lowest (\$4.27 vs. \$3.80/cow per day, compared to \$3.99 vs. \$3.90/cow per day for the low and high SUP respectively). Feeding additional supplement was more "profitable" only when BG was grazed. Milk income minus supplement costs (MIMSC) was \$0.10/cow per day greater for cows eating more

TABLE 3.11. Effect of forage species, stocking rate (SR), and supplementation rate (SUP) on milk income[1] minus supplement costs[2] (MIMSC), assuming supplement intake proportionate to LS means of milk production within a given SUP treatment and calculated on both per cow and per land area bases.

	Tifton 85 bermudagrass				Florigraze rhizoma peanut			
	Stocking Rate[3]				Stocking Rate[4]			
	High		Low		High		Low	
	Supplementation rate (kg/kg of milk per d)							
	0.5:1	0.33:1	0.5:1	0.33:1	0.5:1	0.33:1	0.5:1	0.33:1
MIMSC, \$/cow per d	3.97	3.85	3.83	3.75	3.98	4.26	4.00	4.29
MIMSC, \$/ha per d	34.7	33.7	23.9	23.4	24.9	26.6	15.0	16.1

[1]Estimated milk income = US \$0.33/kg of milk.

[2]Estimated supplement cost = US \$0.22/kg of supplement.

[3]High and low stocking rates were 7.5 and 5.0 cows/ ha in 1995 and 10.0 and 7.5 cows/ha in 1996.

[4]High and low stocking rates were 5.0 and 2.5 cows/ ha in 1995 and 7.5 and 5.0 cows/ha in 1996.

supplement on BG but was $0.29/cow per day lower for cows eating more supplement on RP. These responses reflect the effects of substitution. One aspect of substitution not accounted for in this analysis is the potential for greater SR when feeding more supplement to cows grazing RP pastures.

The greater dollar return on a per cow basis for RP pastures is dwarfed by the greater income per unit land area capable with BG pastures. By these calculations, use of BG resulted in a 40% greater dollar return/ha. Average income/ha for BG was $28.95 vs. $20.65 for cows grazing RP.

Conclusions

Successful utilization of pasture-based forage systems in Florida is likely to depend upon a variety of factors. Along with forage type, SR, supplement type and feeding regime, pasture and animal management factors such as fertilization, forage components for other seasons, types of supplement provided, exogenous growth hormone (bST), cooling systems for cows (trees, shades, ponds, barns with misters and fans), breed differences, and reproductive management must be considered. Further, despite its potential for reduced costs, the rather low production per cow in this study suggests that use of pasture for lactating dairy cows in Florida may limit its consideration by most producers.

For producers using grazing, RP is likely to be of limited use in Florida dairy grazing systems until N fertilizers become prohibitively expensive. The greater milk production/cow associated with RP cannot compensate for the forage's limited ability to support large numbers of lactating cows/ha. Tifton 85 bermudagrass, however, appears

to be an excellent forage for dairy grazing given its relatively high nutritive value characteristics and great yields.

Ability to optimize SR for both animal and forage production will be critical for producer success with grazing. Results from this study indicated that increasing SR on productive forages such as BG might improve forage quality. Stocking rates of 10 cows/ha may not be great enough in conditions of rapid growth of Tifton 85, but this depends upon factors such as rainfall and fertilization practices. At SR of 7.5 cows/ha on RP pastures, HA may limit animal production. Although estimates of OMI suggest that the high SR, low SUP treatment within RP pastures did not limit forage OMI, such high SR may have negative consequences in terms of maintenance and productivity of stand, and would only be advisable under excellent growing conditions.

Providing supplement is a cost-effective way to improve performance of cows on pasture, particularly forages of moderate quality and of more limited availability. The positive milk production and MIMSC responses to additional supplement when cows grazed BG pastures indicate the value of providing supplement to cows grazing this moderate quality forage. However, the limited production response and negative MIMSC response to supplement when cows grazed RP indicates the potential for substitution with high quality forage. Further, the over-prediction of energy input with RP pastures indicates that the supplementation treatments in this study were not effective in combination with RP.

Although several studies have indicated greater response to supplement when forage availability was limited, forage availability likely was not limited in these studies, and no such responses were observed.

Concerns about pasture-based production systems include the losses of BW and body condition, and the poor reproductive performance associated with their use. Cows in these studies were moved directly from barns to pastures in the heat of the summer. No time was given for adaptation to either the heat or the new system of forage consumption, and BW losses were greatest in the first treatment period. In year-round pasture-based systems, however, losses of BW might be reduced due to better adaptation. Further, strategies such as winter calving might limit the losses associated with the heat of summer and allow for greater reproductive success. However, changing the season of production may strain the grazier's ability to utilize rapidly growing summer pastures and may require large supplemental forage inputs during the winter grazing season. Other options for graziers in Florida may include the use of cows better adapted to Florida's climate and improved heat abatement strategies.

CHAPTER 4
PASTURE BASED DAIRY PRODUCTION SYSTEMS: INFLUENCE OF HOUSING, bST, AND FEEDING STRATEGIES ON ANIMAL PERFORMANCE

Introduction

For dairy farmers in the Southeast considering pasture-based production systems for lactating dairy cows, environmental stress is a particular concern. Cool, comfortable cows produce more milk, and in areas where the climate is typically hot and humid, milk production is likely to be compromised due to the inverse relationship between milk production and heat stress tolerance. This situation is exacerbated for pasture dairies by at least three factors. First, as temperature increases, DMI typically decreases to a greater degree with increasing concentration of roughage in the diet. Secondly, more direct exposure to solar radiation results in greater heat load for cows on pasture with limited shelter. Thirdly, grazing cows have larger heats of maintenance due to greater activity (walking and grazing).

Typical cooling methods for pasture systems include cooling ponds, fixed or mobile shade structures, and trees. Technologies for heat stress abatement in confined-housing production systems have seen great advances in the past decade but remain limited for animals on pasture. However, such structures may be available for producers switching to grazing systems, and their efficacy for pasture-based dairy systems have not been tested.

Another possible way to improve production of cows in grazing systems is with the use of bST. Few studies using bST have been conducted with cows grazing pastures

in hot climates. Because of the increase in body temperatures associated with the use of bST, concerns have been raised about its use on heat-stressed cattle. However, review of the literature indicates that cattle may be able to dissipate additional heat production due to bST treatment.

While management strategies such as designed shading and bST improve animal performance, few have investigated their use with lactating dairy cows grazing pasture under hot conditions. This lack of information was the impetus for the study that follows.

Materials and Methods

Cows, Design, and Treatments

On 28 July 1997, 32 multiparous cows (average parity = 2.9; average DIM = 196 ± 38) at the University of Florida Dairy Research Unit were assigned randomly to one of five treatments arranged in two replicates. Treatments were 1) cows maintained on pasture continuously, 2) Treatment 1 plus Posilac® (Monsanto, St. Lousi, MO; **bST**), 3) cows maintained on pasture from approximately 1800 to 0530 h, then in free-stall housing with fans and misters from 0730 to 1530 h, 4) Treatment 3 plus bST, and 5) Treatment 4 plus corn silage fed at 0.5% of body weight (DM basis) in the barn. The bST was injected on d 1 and 13 in Periods 1 and 2. In Period 3, the second dose of bST was delayed to d 15 due to oversight. Cows were assigned to a new treatment for each of the three periods. No cow received the same treatment more than once and the number of changes from a given treatment to another was balanced. Periods 1 and 2 lasted 24 d, and Period 3 lasted 26 d. The first 12 d of each period served to adjust cows to a new treatment. The remaining days of each period were used for data collection.

Pastures (*Cynodon dactylon X C. nlemfuensis* cv. 'Tifton 85') were fertilized with NH_4NO_3 at a rate of 67 kg of N/ha on 18 July and 4 September. Pastures were divided into 16 paddocks, allowing a 15-d rotation. The integrity of bermudagrass (BG) paddocks was maintained with energized polywire fencing. Fencing prevented cows from grazing the next day's forage allotment as well as BG in its regrowth phase. Cows were provided shade structures (80% sun-block shade cloths stretched over metal pipe frames) and water tubs that were moved to a fresh paddock each morning. Shade structures were designed to provide 4.6 m^2 of shade/cow. Stocking rates were 13.3 and 10 cows/ha for cows fed or not fed silage, respectively.

Cows were milked at 0530 and 1630 h. After the morning milking, cows assigned to Treatments 1 and 2 were returned to pastures. Cows assigned to Treatments 3, 4, and 5 were taken to a freestall barn where they were housed within their respective treatment groups. After the p.m. milking all cows were moved to pasture where they remained until the a.m. milking.

Supplement was fed at a rate of 0.50 kg (as-fed)/kg of milk produced per day. Averages of 3- or 4-d milk weights were reviewed twice weekly and the amount of supplement provided was adjusted accordingly. Fifty percent of this daily amount was fed after each milking in the pastures or in the barn, according to treatment assignment. When housed, cows were fed in the barn by treatment group. When cows were on pasture, supplement was fed to each replicate within treatment. Supplement ingredients are listed in Table 4.1. Average nutritive value characteristics of the supplement and forages are reported in Table 4.2.

Table 4.1. Supplement ingredients.

Item	(%, DM basis)
Hominy	35.8
Soybean hulls	23.9
Soybean meal	9.5
Whole cottonseed	20.1
Mineral mix[1]	2.7
Limestone	1.3
Trace mineral salt[2]	1.3
Molasses	4.0
Sodium bicarbonate	1.3

[1]Composition: > 55% Dyna-Mate, > 0.7% 1% Se, > 0.4% $CoSO_4$, > 1.9% $CuSO_4$, > 2.6% $ZnSO_4$, 0.7% $MnSO_4$, 36.9% MgO, > 0.001% CaI, 1200 IU/g of vitamin A, > 700 IU/g of vitamin D_3, > 300 IU/g of vitamin E.

[2]Composition (g/100 g): NaCl, 92 to 97; Mn, > 0.25; Fe, > 0.2; Cu, > 0.033; I, > 0.007; Zn, > 0.005; Co, > 0.0025.

Table 4.2. Chemical composition, and nutritive value of supplement, corn silage and bermudagrass pasture.

	Feedstuff		
Item	Maize Silage[1]	Supplement	Bermudagrass[2,3]
Dry matter, %	26.2	92.5	--
IVOMD, %	65.6	--	60.3
TDN, %	62.0	76.0	57.4
NEL, Mcal/kg	1.38	1.83	1.29
NDF, %	57.2	38.0	77.6
ADF, %	33.4	23.0	35.1
CP, %	7.97	17.35	14.7
Ash, %	3.4	9.1	5.1
Ca, %	0.25	1.16	0.41
P, %	0.27	0.52	0.31
Mg, %	0.18	0.33	0.26
K, %	1.11	1.35	1.70
Na, %	0.013	1.27	0.038
S, %	0.11	0.20	0.29
Cl, %	0.3	1.24	0.53
Fe, ppm	51	503	55
Zn, ppm	26	194	38
Cu, ppm	4	48	5
Mn, ppm	22	93	42
Mo, ppm	<1	<1.4	1.3

[1]Estimate of TDN and NEL from NRC (1989) for corn silage, few ears.

[2]Estimate of TDN calculated with the following equation: % TDN = [(%IVOMD*0.59) + 32.2] * OM concentration (J. E. Moore, personal communication).

[3]NEL calculated from the estimate of TDN described in Footnote 2, using NRC (1989) equations: NEL = [0.0245*TDN(% of DM) – 0.12].

Five days prior to the experiment's start, all cows were moved into the freestall barn for adaptation. At this time, cows were fed a diet consisting of a mixture of the farm's high-herd TMR, corn silage, and the experimental supplement. The high-herd TMR portion of the diet was phased out over 5 d with an increasing percentage of supplement and corn silage being fed.

Experimental Measurements

Milk production, body weight, and body condition score. Milk weights were recorded at each milking. Milk samples were collected at six consecutive milkings within the last 12 d of each period. Samples were analyzed by Southeast Dairy Labs (McDonough, GA) for milk fat and protein percentages, somatic cell count (**SCC**), and milk urea nitrogen (**MUN**).

Cows were weighed after the a.m. milking on three consecutive days at the initiation of the trial and at the end of each period. Body condition scores were recorded on one of the weigh days within each period (Wildman et al., 1982).

Respiration rates and body temperatures. Respiration rates were measured by monitoring the movement of the flank or bobbing of the head over a 1-min interval. Measures took place during the afternoon before the p.m. milking during a time of greatest potential ambient temperature.

Body temperatures were not measured in Period 1 because the units for measuring body temperatures were unavailable. In Periods 2 and 3, fifteen cows (three per treatment) were used to determine the effect of treatment on body temperature. Intra-vaginal telemetric temperature transponders (Telonics®, Mesa, AZ) were used to record body temperatures. Since only five temperature transponders (**TT**) were available, one

cow per treatment was fitted with a TT and temperatures measured for 48 h. This was repeated for a second and third group of five cows each. The TT were taped to progesterone-free Eazi Breed™, controlled intravaginal drug releasing devices (InterAg, Hamilton, NZ) and inserted into the vagina.

Each TT broadcast a signal at its own frequency, and the frequencies were preset into a radio scanner. The scanner moved sequentially through the preset TT frequencies, recording three signals per given TT in approximately 1 min. Thus, a set of three readings for all treatments was obtained approximately every 5 min.

Factoring out 2 h for set-up, installation and TT adaptation, the theoretical maximum number of readings per treatment was approximately 10,000 (36 readings/h per cow times 46 h times 3 cows per treatment-period times 2 periods). Differences in TT signal strength, distance from TT to the scanner (0.75 km maximum), computer shut-down, and environmental and atmospheric conditions often resulted in loss of signals, or signals which did not represent physiological temperatures. Across the two periods, an average of 4400 readings were taken for cows on pasture and 5400 readings for cows in the barn.

Plasma metabolites. Blood samples were collected from the coccygeal vessels thrice at 2- to 4-d intervals within the last week of each period. Vacutainors™ (Becton Dickinson, Franklin Lakes, NJ) containing EDTA were used for the first sample taken. At the remaining 8 dates, blood was collected into 9-ml Na-heparinized (Luer Monovette® LH, Sarstedt, Inc., Newton, NC,) syringes. Blood was sampled after the p.m. milking and placed on ice. Blood was then centrifuged for 0.5 hr (2000 x g), plasma collected, and plasma frozen at –20°C for future analyses.

Glucose in plasma was analyzed following the colorimetric procedure of Gochman and Schmitz (1972). Plasma was filtered with 16 X 174 mm standard model serum filters (Fisherbrand®, Fisher Scientific, Pittsburgh, PA) and analyzed directly with an automated analyzer (Bran+Luebbe, Model II, Bran+Luebbe Analyzing Technologies, Elmsford, NY).

Plasma hormones. Double antibody radioimmunoassay was performed for determination of insulin and insulin-like growth factor-1 (**IGF-1**) following the procedures of Abribat et al. (1990). Second antibodies for use in the assays were prepared in Florida native sheep maintained at the University of Florida Dairy Research Unit. Sheep were injected subcutaneously with guinea pig and rabbit gamma globulins and reinjected 2 wk later. Sheep were bled at 2 and 6 wk after the second injection and the serum obtained was pooled and frozen. Second antibodies of sheep anti-guinea pig and sheep anti-rabbit in the pooled plasma were used in the assays. For a complete description of the antibody collection, preparation, and iodination methods, see Garcia-Gavidia (1998).

Plasma insulin concentration was determined following procedures described by Soeldner and Sloane (1965) as modified by Malven et al. (1987). Approximately 100 µg of highly purified insulin (Sigma Immunochemicals, St. Louis, MO) was dissolved in 30 mM of HCl (pH = 2.5) in an ultrasonic water bath. This stock insulin was diluted in an assay buffer of 0.33 M borate, 0.01% merthiolate, and 0.5% BSA to give a final concentration of 100 ng/ml. Standards of 0, 0.3, 0.5, 1.0, 2.0, 4.0, 6.0, 8.0, 10, 15, 20, 25, and 30 ng insulin/ml were prepared from the solution of insulin in the BSA buffer. First antibody (guinea pig anti-bovine insulin, Sigma Chemical, Co., St. Louis, MO) was

dissolved in assay buffer with BSA at 1:20,000, and sheep anti-guinea pig second antibody was diluted in borate/EDTA assay buffer.

Plasma samples (100 µl) were pipetted into 12 x 75 mm borosilicate tubes (in duplicate) to which 100 to 200 µl of assay buffer with BSA then was added. Immediately afterward, 100 µl of primary antiserum were added to all but the total count and non-specific binding tubes, and all tubes received 100 µl of iodinated (I^{125}) insulin. Samples were vortexed 60 s on a plate vortexer and incubated for 24 h at 4°C. After incubation, 100 µl of sheep anti-guinea pig second antibody and 100 µl of normal guinea pig serum (1:100) were added to all but the total count tubes. After incubating for 10 min, 0.75 ml of 15% polyethylene glycol in borate buffer were added to all tubes except total count tubes. Tubes then were vortexed, incubated for 10 min, centrifuged (2000 x g) in a refrigerated (4°C) centrifuge (RC-2B, refrigerated centrifuge, Sorvall® Instruments, Newtown, CT) for 30 min, decanted, and inverted on absorbent paper till dry. Bound radioactivity in dry tubes was measured with a Packard® auto gamma counter (model B-5005) and results were calculated by the spline radioimmunoassay data processing procedure.

IGF-1 was extracted from its binding proteins following the procedure of Enright et al. (1989). The extract solution was a 60:30:10 mixture (by volume) of ethanol, acetone, and acetic acid. The extraction mixture (400 µl) was added to 100 µl of well-mixed plasma in 12 x 75 mm borosilicate tubes and the two were mixed thoroughly for 15 sec on a vortexer and then allowed to stand for 30 min. Tubes then were centrifuged (2000 x g) in a refrigerated (4°C) centrifuge for 30 min (RC-2B). Supernatant (250 µl) was transferred to 12 x 75 mm polystyrene tubes. To neutralize the extraction mixture,

100 μl of 0.855 M Trizma base were added. A final 1:14 dilution was made by adding 350 μl of assay buffer.

The IGF-1 (highly purified Human IGF-1 from Upstate Biotechnology, Inc., Richmond, CA) for iodination was dissolved (0.5 μg/μl) in 0.1-M acetic acid (pH = 2.5). Highly purified bovine IGF-1 supplied by Monsanto Company (St. Louis, MO) was dissolved in 0.1-M acetic acid (10 μg/100 μl) to prepare Stock 0. Stock solutions 1 and 2 were made by adding 10 μl of Stock 0 to 490 and 990 μl of assay buffer, respectively. Using Stock 2, standards containing 0, 50, 100, 200, 300, 400, 500, 600, 800, 1000, 1200, 1500, and 1500 pg of IGF-1/ml were prepared.

First antibody, rabbit anti-bovine IGF-1 was provided by Drs. Louis Underwood and Judson J. Van Wyk, Division of Pediatric Endocrinology, University of North Carolina, Chapel Hill, NC. The first antibody was dissolved in assay buffer [200 mg of protamine/l, 4.4 g/L of sodium monobasic phosphate, 10 ml of 2% sodium azide, 3.72 g/L of EDTA (0.013 M), and 2.5 g/L of BSA] at a 1:4000 ratio. Second antibody (sheep anti-rabbit) was diluted in EDTA-PBS for use.

Ten microliters of plasma extract were combined with 190 μl of assay buffer in duplicate. One hundred μl of diluted primary antiserum and iodinated IGF-1 were both added to all tubes immediately thereafter. Tubes were vortexed on a plate vortexer and allowed to incubate for 20 to 30 h at 4°C. Diluted sheep anti-rabbit antibody (100 μl) and 50 μl normal rabbit serum (1:50) were added to all but total count tubes and allowed to stand for 30 min. Assay buffer with 6% polyethylene glycol (1 ml) then was added to all but total count tubes. Tubes were vortexed, allowed to stand for 15 min, centrifuged for 30 min (2000 x g) at 4°C (RC-3B, refrigerated centrifuge, Sorvall Instruments), and then

decanted. After draining and drying on absorbent paper, bound radioactivity in tubes was measured using a Packard® auto gamma counter (model B-5005) and results were calculated by the spline radioimmunoassay data processing procedure.

Grazing time and organic matter intake. Grazing time was measured in periods 1 and 2 using vibracorders (Kienzle Co., Germany). Each cow's grazing activity was recorded for 24 h in Period 1and for 48 h in Period 2. The vibracorders were fastened to metal yokes that were hung over the neck of the cows and fastened with cloth belts and metal buckles. A freely swinging pendulum with an attached stylus inside the vibracorders marked waxed charts. At the end of each measurement period the charts were collected. A planimeter was used to measure the markings on the chart to estimate grazing time.

Chromium-mordanted fiber was used as an inert marker to determine dry matter intake. In Periods 1 and 2, 10 to 15 forage samples were collected across all pastures and composited. Efforts were made to gather forage of quality similar to that estimated to be consumed. Fiber from the forage was chromium mordanted according to the method of Udén et al. (1980). Forages were dried at 55°C and ground with a stainless steel 2-mm screen (Thomas-Wiley Laboratory Mill, Thomas Scientific™, Philadelphia, PA). The dried, ground forage was boiled approximately 2 h in a mixture of water and liquid laundry detergent (approximately 100 g of forage/L of solution) to isolate the cell wall fraction. After boiling, the fiber was washed repeatedly with water to remove all soap, rinsed with acetone, dried at 105°C, and weighed. The dried forage (500 to700 g) was placed in an 8-L metal container. Sodium dichromate (100 to 140 g) was dissolved in approximately 4 l of water and added to the forage. Addition of chromium (as sodium

dichromate) equaled 7% of the fiber DM. This slurry was sealed with aluminum foil and heated at 105°C for 24 h in a drying oven. The liquid was poured off and the fiber was rinsed gently to remove unbound Cr. Ascorbic acid (Aldrich®, Milwaukee, WI) at half the dry fiber weight was mixed with water, added to the fiber, and allowed to stand for 1 to 1.5 h. The fiber was rinsed thoroughly with tap water and dried at 105°C. Three ± 0.02 g of mordanted fiber were weighed into 28-g gelatin capsules (Jorgenson Laboratories, Loveland, CO). Excess mordanted fiber prepared for use in Periods 1 and 2 were combined for use in Period 3. Average Cr concentration in the mordanted fiber for dosing was 62,700 ppm (OM basis).

In each period, all cows on trial were dosed orally with nine gelatin capsules containing Cr-mordanted fiber (27 g, as-fed). Capsules were administered with a multiple dose balling gun (NASCO, Ft. Atkinson, WI). Cows were dosed after the evening milking 3 d prior to the end of each period. Samples of feces were collected via rectum at 0, 12, 15, 18, 21, 24, 27, 36, 42, 48, 60, 72, and 84 h post-dosing. Collections were made on pasture at approximately h 15, 18, 21, 27, and 42 as volunteered by the cow.

Fecal samples were refrigerated (maximum time of 96 h) until they could be dried (55°C for a minimum of 48 h). Dry samples were ground through a 1-mm screen (Thomas-Wiley Laboratory mill, Philadelphia, PA). Ground samples (2 g) were dried at 105°C and ashed at 550°C for determination of DM and OM according to AOAC (1990) procedures. Ash was digested on a hot plate in a solution containing H_2PO_4 (with added $MnSO_4$) and $KBrO_3$ and analyzed for Cr by atomic absorption spectrophotometry

(Atomic Absorption Spectrophotometer, Model 5000, Perkin Elmer, Norwalk, Conn.) following the methods of Williams et al. (1962).

Results from the intake study were evaluated with PROC NLIN using the method of Pond et al. (1987; Appendix 1). Parameters generated by this program were used to estimate fecal output for each cow. Estimates were based on the following assumptions:

1) supplement intake was the same for all cows within a pasture replicate,
2) supplement digestibility was constant regardless of forage intake,
3) digestibility of forage was affected by the level of supplement intake, as determined by the equation of Moore et al. (1999; Appendix 2).

Theoretically, fecal output should equal total intake multiplied by the indigestible fraction of a feed. Because fecal output observed, based on the mordanted-fiber methodology, was not equal to the fecal output predicted based on forage and supplement digestibilities, an iterative SAS (1991) program (developed by Dr. J. E. Moore) was employed to adjust the estimate of bermudagrass intake until the difference between fecal output observed and predicted differed by less than 0.01 kg/d (Appendix 2).

Expected diet digestibility (%) = [(bermudagrass intake, kg * bermudagrass digestibility, %) + (silage intake, kg * silage digestibility, %) + (supplement intake, kg * supplement digestibility, %)]/total intake, kg. Because feeding concentrate supplements often alters forage digestibility (Arriaga-Jordan and Holmes, 1986; Berzaghi et al., 1996), the iterative program also employed the equation of Moore et al. (1999; Appendix 2 to adjust total diet digestibility.

Feed sampling. Forage was collected once each period to characterize forage nutritive value (Table 4.2). Forage was collected in a manner similar to that used for

chromium mordanting as previously described. Samples taken from a fresh paddock in each pasture were dried at least 48 h at 55°C, and ground through a 1-mm screen (Thomas-Wiley Laboratory mill, Philadelphia, PA). Samples within pasture within period were analyzed by the University of Florida Forage Evaluation Support Laboratory, Gainesville. For determination of organic matter (**OM**), dried samples were ashed for at least 4 h at 500°C. The modified aluminum block procedure of Gallaher et al. (1975) was used to digest samples prior to analysis for N by the method of Hambleton (1977). Crude protein (**CP**) was then calculated as N * 6.25. Determination of neutral detergent fiber (**NDF**) and IVOMD concentrations were made using the procedures of Golding et al. (1985) and Moore and Mott (1974), respectively.

Silage and supplement samples were collected three times in each period (approximately every 8 d) and frozen till future analysis. Silage samples were dried at 55°C for 48 h for determination of % DM. Dried silage was ground, and an equal weight of sample within period was composited and submitted to the DHI Forage Testing Laboratory, Ithaca, NY, for analysis. Equal weights (as-fed basis) of supplement were composited by period and submitted to the above lab for analysis.

Statistical Analysis

Animal measures. One cow was removed from the trial during Period 2 due to a health problem unrelated to treatment. A replacement cow was used in Period 3 to maintain the stocking rate, but her data were not used in the analyses.

Most data were analyzed using the GLM procedure of SAS (1991) with the following model:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + \gamma_{k(j)} + \Delta_l + \epsilon_{ijkl},$$

where

μ = overall mean

α_l = effect of cow

β_j = effect of treatment

$\gamma_{k(j)}$ = effect of pasture(trt)

Δ_l = effect of period

ϵ_{ijkl} = effect of residual error.

Single degree of freedom contrasts for treatment were housing (1 + 2) vs. (3 + 4), bST (1 + 3) vs. (2 + 4), interaction (1 + 4) vs. (2 + 3), and silage supplement (4 vs. 5). Treatment effects were considered significant at P levels < 0.05 and trends at P < 0.10.

Temperature measures. Plots of the temperature data were evaluated visually and readings exhibiting spontaneous spiking and readings outside of 38 to 40°C were deleted. Greater signal variability for cows on pasture resulted in an average of 13.7% of readings being deleted vs. an average of 8.5% of readings deleted for cows in the barn.

Visual evaluation showed three general trends in the data. First, an increase in body temperature was observed through the daylight hours until the p.m. milking. Secondly, a parabolic decrease and subsequent increase in temperature was observed as cows went onto showers for cleaning, were milked, and returned to pasture. Thirdly, a decrease in temperature was observed through the night until after the a.m. milking.

To evaluate the curves, the data were divided into these respective segments on the horizontal (time) axis. Because barn and pasture cows did not arrive at the shower at the same time and because time on the showers and time back to pasture varied slightly for each group, further adjustments on the horizontal axis were necessary. For Segment

1, all data were shifted so that peak temperature for all cows occurred at 1624 h, just before milking. For Segment 2, the time from peak pre- to peak post-shower temperatures was adjusted to equal 2 h 42 min. This adjustment allowed the minimum temperature for all cows in section 2 to occur at 1745 h, during the time of showering, milking, and drinking. Segment 3 data were shifted so that all cows had near-peak or peak temperature at 1906 h, when cows returned to pasture.

After adjustments, data were modeled by segment using PROC MIXED procedure of SAS (Littell et al., 1996). Because our interest was in plotting the effect of treatment over time without individual cow effects, cow was not included in the model.

Regression coefficients generated from the analysis were used to plot the data. The resultant curves were evaluated visually for congruity of temperature between segments. Since the generated curves were not always congruent from one section to the next, algebraic operands using dummy variables were applied to the original data set to force the joining of sections within each curve (Draper and Smith, 1981). Both PROC MIXED and PROC GLM were used to evaluate the adjusted curves. The curves were modeled using PROC GLM since the PROC MIXED method partitioned out only very little variability due to cow within treatment and period. (After partitioning, overall residual error was greater than residual error due to Cow(treatment by period) by a factor greater than 10^6.)

Several different points in time (hour) were substituted into the model equation and the ESTIMATE procedure of GLM was then used to calculate differences in temperature between treatments. After taking the derivative of the model equation with

respect to hour (d*y*/d*hour*), the ESTIMATE procedure was used to determine differences among the slopes of the treatments.

Results and Discussion

Grazing Time and Intake of Organic Matter

Effect of housing. Per design, keeping cows in the barn limited their opportunity to graze (Table 4.3). Cows on pasture spent more time ($P < 0.001$) in grazing activities as measured by vibracorder than did cows kept in the barn from 0800 to 1500 h (6.9 vs. 5.3 h of grazing time/cow per d). The estimates of grazing time for cows grazing pastures through the day in this study are less than those reported by Stobbs (1970), who tested a variety of forage species and fed little supplement. Results are similar to those of Combellas et al. (1979) who reported 6.6 hours of grazing/d for heifers receiving 6 kg/d of supplement. However, direct comparison of grazing times is difficult due to differences in milk production, BW, environment, forage species, and pasture management.

Though grazing time was greater for cows on pasture, grazing intensity appeared greater for cows housed in barns (Figure 4.1), and the estimates of forage OMI indicate that grazing time did not affect forage intake (Table 4.3). Average forage OMI of BG, excluding cows on the silage treatment, was 9.2 kg/d, or 1.58% of BW. Because forage OMI was unaffected by grazing time, housed cows must have grazed with greater harvesting efficiency [defined as intake over time (Barton et al., 1992; Krysl and Hess, 1993)]. This might have occurred as a result of an increased bite rate due to temporary deprivation from pastures as has been reported by Greenwood and Demment (1988).

Table 4.3. Influence of housing (0800 to 1500 h on pasture or in barns with fans and sprinklers), bST, and bST with supplemental silage on organic matter intake (OMI) of Holstein cows grazing Tifton 85 bermudagrass pastures.

	--- Pasture ---		------ Barn ------				-------- Probability[1] --------			
Item	-bST	+bST	-bST	+bST	+silage +bST	SEM	Housing	bST	Housing x bST	Silage
Grazing time, h/d	6.5	7.2	5.0	5.6	4.0	0.4	***	*	NS	***
BG[2] OMI, kg/d	9.5	9.4	8.9	9.0	7.4	0.6	NS	NS	NS	***
Sup.[3] OMI, kg/d	6.7	8.0	7.3	7.9	7.8	0.2	NS	***	*	NS
Silage OMI, kg/d	-	-	-	-	3.0	-	-	-	-	-
Total[4] OMI, kg/d	16.2	17.4	16.2	16.9	18.2	0.5	NS	**	NS	**
BG OMI, %BW[5]	1.65	1.61	1.52	1.54	1.25	0.10	NS	NS	NS	***
Sup. OMI, %BW	1.16	1.37	1.26	1.35	1.32	0.04	NS	***	*	NS
Silage OMI, %BW	-	-	-	-	0.53	-	-	-	-	-
Total OMI, %BW	2.81	2.98	2.78	2.89	3.10	0.09	NS	*	NS	*

[1]P < 0.001, 0.01, 0.05, and 0.10 represented by ***, **, * and †, respectively.
[2]Tifton 85 bermudagrass.
[3]Supplement.
[4]Total OMI – (BG OMI + Sup. OMI) = silage OMI of cows receiving the barn + silage + bST treatment.
[5]Body weight.

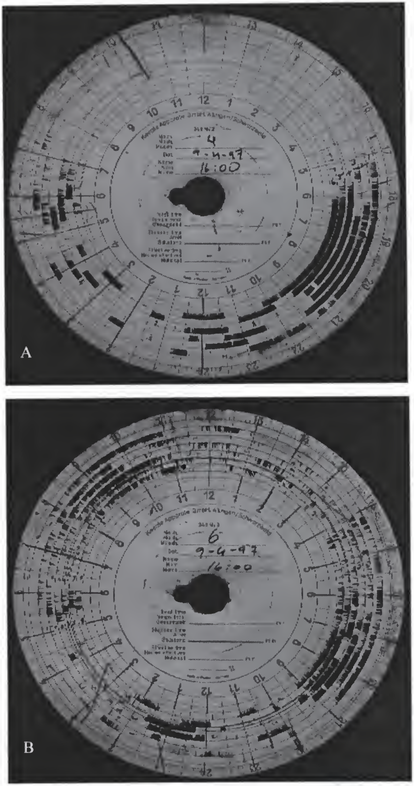

Figure 4.1 Vibracorder charts for cows treated with bST and housed in barns from 0800 to 1500 h (A) and for cows housed on pasture (B). Note the greater grazing intensity for cows housed in the barn during the day.

Housing had no effect on supplement intake (7.4 vs. 7.6 kg of OM/d for unhoused and housed cows, respectively), corresponding with milk production responses. Total OMI/d also were unaffected by housing treatment with OMI of 16.8 and 16.6 kg/d (2.90 and 2.84% of BW) for unhoused and housed cows, respectively.

Effect of bST. Cows treated with bST grazed approximately 45 min more ($P < 0.05$) than untreated cows (6.3 vs. 5.6 h of grazing/d) each day, however, forage OMI was unaffected by bST treatment. Given the conditions imposed, cows treated with bST would not be expected to increase intake of forage OM since supplement provided was increased with increasing milk production.

For bST-treated cows consuming only pasture, forage intakes likely will increase given adequate amounts of available herbage (Hoogendoorn et al., 1990). While intake responses to bST treatment for cows grazing pasture may not be observed directly (Hoogendoorn et al., 1990) or only slowly discernable (e.g., after 22 wk; Peel et al., 1985), Michel et al. (1990) reported increases in pasture intake within 4 wk of initial bST administration. D'Urso et al. (1998) reported that ewes increased intake due to bST treatment, particularly at greater SR. The authors reported that hormone-treated animals grazed less selectively and ate faster.

The OMI from supplement increased for bST-treated cows because of the management strategy of feeding the amount of supplement based on milk production. Cows injected with bST averaged 8.0 kg of supplement OMI/d vs. 7.0 kg/d for untreated cows. Based on the supplementation strategy of feeding 0.5 kg of supplement (as-fed basis)/kg of daily milk production, it appears that cows on pasture and treated with bST received excess supplement. However, this may be an artifact of using least squares

means because supplement OMI matched the raw means for milk production of each treatment.

Increased supplement OMI in response to bST treatment was greater for cows kept on pasture than for cows kept in barns during the day (housing by bST treatment interaction, $P < 0.05$), matching raw means of milk production.

Across all treatments, total OMI averaged 17.0 kg/d (2.87% of BW) and were greater than those reported for TMR-fed cows in a similar stage of a lactation and milk production under heat stress conditions (Staples et al., 1988). Housing had no effect on total OMI/d, contradictory to the results of Zoa-Mboe et al. (1989).

Effect of supplemental silage. Feeding silage curtailed grazing time by more ($P < 0.001$) than 25% (5.6 vs. 4.0 h of grazing/d). Phillips and Leaver (1986) noted that the effect of supplemental forage provision on grazing time depended on whether the supplemental forage was a substitute for or a supplement to the grazed forage. With decreased grazing time came a concomitant decrease ($P < 0.001$) in BG OMI of about 18% (from 9.0 to 7.4 kg/d, respectively). However, total forage OMI was increased approximately 17% with supplemental silage (from 9.0 to 10.5 kg of forage OMI/d). Moran and Stockdale (1992) also compared intake and milk production of cows fed pasture alone or pasture with supplemental corn silage. They reported no effect of silage on pasture DMI, but pasture intake was numerically less than that for unsupplemented cows.

As feeding silage did not affect milk production, supplement OMI was not different between the two silage treatments. Cows fed silage consumed more ($P < 0.01$) total OMI per day by nearly 8%. Whereas the equation of Moore et al. (1999) was used

to adjust forage digestibility due to associative effects of supplement feeding and thus forage intake estimates, no additional adjustments to forage digestibility were made for cows consuming corn silage. If feeding corn silage resulted in a greater depression of forage digestibility, OMI was over-predicted.

Milk Production and Composition

Effect of housing. Daytime housing with fans and sprinklers did not affect milk production ($P < 0.11$) of cows. Numerically, however, housed cows produced nearly 5% more milk than unhoused cows (17.8 vs. 17.0 kg/cow per d, respectively) (Table 4.4). Housing cows during the day tended ($P < 0.10$) to increase production of 4% FCM by 5.5% (17.2 vs. 16.3 kg/d).

That differences between housing regimes did not significantly affect raw milk production in this study is surprising given the greater energy expenditure of cows kept on pasture. Maintenance costs for heat stressed cows increase above thermoneutral, but intake typically declines with increasing temperature; thus milk production decreases (Collier and Badenga, 1985). The greater milk production from housed cows despite having similar OMI to those of pastured cows indicates a greater efficiency of nutrient utilization for housed cows. It is certain that housed cows expended less energy for maintenance because they walked less and experienced less heat stress.

Using cows of low milk production may have limited the ability to detect treatment differences. Comparisons of shade vs. evaporative cooling using cows producing much greater quantities of milk have been made (Chan et al., 1997; Chen et al., 1993). Chan et al. (1997) reported a tendency of increased milk production with

4.4. Influence of housing (0800 to 1500 h on pasture or in barns with fans and sprinklers), bST, and bST with supplemental silage on milk production and composition of Holstein cows grazing Tifton 85 bermudagrass pastures.

	--- Pasture ---		------ Barn ------				-------- Probability --------			
Item	-bST	+bST	-bST	+bST	+silage +bST	SEM	Housing	bST	Housing x bST	Silage
Milk yield, kg/d	16.2	17.7	17.0	18.5	17.9	0.6	NS	**	NS	NS
4% FCM[1], kg/d	15.3	17.3	16.3	18.0	17.6	0.6	†	***	NS	NS
Milk fat, %	3.65	3.80	3.76	3.85	3.90	0.04	NS	NS	NS	NS
Milk fat, kg/d	0.59	0.68	0.64	0.70	0.69	0.03	NS	***	NS	NS
Milk protein, %	3.22	3.23	3.23	3.27	3.26	0.03	NS	NS	NS	NS
Milk protein, kg/d	0.52	0.57	0.54	0.60	0.58	0.02	†	***	NS	NS
MUN[2], mg%	18.0	18.5	18.1	18.0	15.5	0.3	NS	NS	NS	***
SCC[3], x 1000 cells	747	610	443	834	545	236	NS	NS	NS	NS

[1]P < 0.001, 0.01, 0.05, and 0.10 represented by ***, **, * and †, respectively.
[2]Fat corrected milk.
[3]Milk urea nitrogen.
[4]Somatic cell count.

evaporative cooling similar to the increases found in this study, while Chen et al. (1993) noted a 9% increase in milk production with evaporative cooling over shade alone.

Milk fat percentage was unaffected by treatment, but housed cows tended to have numerically greater ($P < 0.12$) milk fat production. Cows kept in the barn during the day tended ($P < 0.10$) to produce greater quantities of milk protein (0.57 vs. 0.55 kg/d) than cows on pasture, largely due to milk production.

Effect of bST. Injections of bST increased ($P < 0.01$) milk production approximately 9% (18.1 vs. 16.6 kg/d) (Table 4.4). Use of bST increased ($P < 0.001$) production of 4% FCM approximately 12% (17.7 vs. 15.8 kg/d).

In a review, West (1994) reported that responses to bST treatment by cows in hot environments ranged from 3.4 to 48.6%, and response to bST typically decreased with increasing amount of pre-treatment milk production (Lotan et al., 1993; West et al., 1990). Thus, given the relatively low amount of pretreatment milk production, greater responses to bST might have been expected. However, the percentage increase in production in response to bST was similar to that found by Staples et al. (1988) whose cows produced similar quantities of milk in a 30-d trial.

Estimates of nutrient intake based on NRC recommendations suggest that nutrient intake did not prevent cows on this trial from producing 20 kg of 4% fat corrected milk/d (Table 4.5). This suggests that either maintenance costs were greater than NRC (1989) estimates, or nutrient intake, particularly energy, was overestimated.

Although bST treatment did not affect milk fat concentration, the greater percentage increase in 4% FCM production compared to the percentage increase in milk production (12 vs. 9%) partially resulted from numerically greater concentrations of milk

TABLE 4.5. Calculated daily intake of nutrients by cows grazing Tifton 85 bermudagrass (BG) pastures and not treated (-bST) or treated (+bST) with exogenous growth hormone. An additional treatment tested the effect of feeding corn silage (Silage) to cows treated with bST.

	Ingredient															
Item	NEL	DM	NDF	ADF	CP	Ca	P	Mg	K	Na	S	Cl	Fe	Zn	Cu	Mn
	Mcal/d	kg/d				g/d							mg/d			
-bST																
BG	12.5	9.7	7.5	3.4	1.4	40	30	25	164	4	28	51	530	365	49	411
Supplement	14.1	7.7	2.9	1.8	1.3	89	40	25	104	97	15	95	3869	1490	331	716
Silage	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Total	26.6	17.4	10.5	5.2	2.8	129	70	50	268	101	43	146	4400	1855	380	1127
+bST																
BG	12.5	9.7	7.5	3.4	1.4	40	30	25	164	4	28	51	530	365	49	411
Supplement	15.9	8.7	3.3	2.0	1.5	100	45	28	117	110	17	107	4372	1683	374	809
Silage	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Total	28.4	18.4	10.8	5.4	2.9	141	75	53	281	114	45	159	4902	2049	423	1220
+bST + Silage																
BG	10.1	7.8	6.1	2.8	1.1	33	24	20	132	9	23	41	426	294	39	330
Supplement	15.7	8.6	3.3	2.0	1.5	99	45	28	116	109	17	106	4322	1664	370	800
Silage	4.4	3.2	1.8	1.1	0.3	8	9	6	36	0	3	10	162	84	13	69
Total	30.2	19.6	11.2	5.8	2.9	140	77	54	284	112	43	157	4910	2042	422	1199
Requirement[1]	23.3	16.0	4.5	3.4	2.2	84	54	32	144	29	32	40	800	640	160	640

[1]Calculations based on NRC requirements for a 500 kg cow producing 20 kg of 4.5% FCM and gaining 0.275 kg/d. Intake was assumed to be 3.2% of BW.

fat from cows treated with bST. The numerical increases in milk fat concentration are consistent with reports of increased milk fat concentration due to bST treatment in short-term trials and especially when cows are in negative energy balance (Chalupa and Galligan, 1989; Hoogendoorn et al., 1990). This suggests that the increased feed provided to cows treated with bST (due to increased milk production) did not completely compensate for the increased energy associated with increased milk production. However, calculation of energy balance using NRC (1989) equations and feed intake estimates did not confirm differences in energy balance due to bST treatment (data not shown).

Increased ($P < 0.001$) daily production of milk fat and milk protein occurred primarily because of the increase in milk production due to bST (Table 4.4).

Effect of supplemental silage. Feeding supplemental silage in the barn had no effect on milk production, 4% FCM production, nor milk fat and protein concentrations or quantities. Similar results have been reported by Australian researchers utilizing mixed warm- and cool-season pastures (Moran and Stockdale, 1992) and by researchers studying use of corn silage with temperate pastures (Holden et al., 1995).

When pasture was limited or when supplemental forage was of greater quality than the grazed forage, milk yield typically increased with silage inclusion (Huber et al., 1964; Phillips, 1988). No difference in herbage disappearance due to any treatment was observed (data not shown). The lack of influence of silage supplementation indicates that forage availability did not limit production of cows fed silage and also implies that the increased stocking rate used for that treatment was appropriate.

The equation used to predict NE_L of BG and silage indicates the BG to be of much lesser energy concentration, but this likely underestimates the quality of the BG. West et al. (1997) reported that Tifton 85 can make up a substantial portion of dairy cow rations with limited effect on intake and production. The authors reported that the NDF of BG underwent greater and more rapid in vitro digestion than NDF of corn silage and rates of passage were not different between the cows fed a corn silage-based control diet and diets having 30% BG hay, despite the fact that the BG diet was nearly 40% greater in NDF concentrations.

Body Weight and Condition

Effect of housing. Housing cows during the day promoted weight gain. Cows kept on pasture lost ($P < 0.001$) approximately 11 kg of BW/24-d period, but cows kept in the barn gained approximately 6 kg of BW/24-d period (about 1% of BW/month) (Table 4.6). These differences in BW changes further highlight the lower maintenance costs for housed cows due to reductions in activity and heat stress.

Effect of bST. On average, cows treated with bST gained small amounts of BW (2.5 kg/24-d period), but cows not given bST lost about 7 kg of BW/24 d period (Table 4.6). The BW gain response was likely a result of the increased supplement provided to bST-treated cows.

Effect of supplemental silage. Cows receiving silage tended ($P < 0.10$) to not gain as much as those not fed additional roughage in the barn. Because OMI was increased for cows fed silage with no change in milk production, partitioning of nutrients to BW gain might be expected. However, changes in BW do not necessarily "reflect changes in body reserves, particularly in trials with a change-over design and involving feeds with different physical characteristics" (Combellas et al., 1979, p. 308). Cows not

Table 4.6. Influence of housing (0800 to 1500 h on pasture or in barns with fans and sprinklers), bST, and bST with supplemental silage on body weight (BW), body condition score (BCS), respiration rates (RR), and concentrations of plasma insulin and insulin-like growth factor-1 (IGF-1) of Holstein cows grazing Tifton 85 bermudagrass pastures.

	Pasture		Barn				Probability[1]			
Item	-bST	+bST	-bST	+bST	+silage +bST	SEM	Housing	bST	Housing x bST	Silage
ΔBW[2], kg/24-d	-12.9	-8.8	-1.3	13.8	5.4	5	***	**	NS	†
ΔBCS[3]/24-d	-0.17	-0.29	-0.24	-0.04	-0.29	0.14	NS	NS	NS	NS
RR, breaths/min	89	88	69	70	68	2	***	NS	NS	NS
IGF-1, ng/ml	88	141	91	144	146	7	NS	***	NS	NS
Insulin, ng/ml	0.58	0.61	0.52	0.57	0.61	0.01	*	†	NS	NS

[1]$P < 0.001$, 0.01, 0.05, and 0.10 represented by ***, **, * and †, respectively.

[2]Change in body weight.

[3]Change in body condition score.

fed supplemental silage could have had greater gut fill because they consumed more BG which contained greater concentrations of fiber and indigestible OM. Because neither milk production nor weight gain increased with the increased OMI, efficiency of nutrient utilization may have decreased with supplemental corn silage, or intake of metabolizable energy may not have been increased. All cows lost body condition and the losses were typical for cows on pasture in the summer. Feeding silage tended ($P < 0.11$) to lower body condition score, but numerical changes indicated greater tissue losses for cows receiving the additional forage (Table 4.6). Others (Moran and Stockdale, 1992; Holden et al., 1995) reported numeric increases in BW gain or condition score with similar levels of supplemental silage, but the trials were 8 to 10 wk in duration. Our results may be a consequence of the postulated difference in gut fill between the two treatments and if so indicates that condition score measurements were based upon more than changes in fat depot size.

Plasma IGF-1 and Insulin

Effect of housing. Housing had no effect on IGF-1 at any sampling date. McGuire et al. (1995) reported 50% reductions in circulating IGF-1 concentrations 48 h after the initiation of feed deprivation, but differences due to short-term deprivation were undetectable.

Greater ($P < 0.05$) insulin concentrations were detected for cows kept on pasture continually. Average concentrations were 59.5 and 54.5 ng of insulin/mL for pasture and barn cows, respectively. Others have reported decreased plasma insulin concentrations during the summer (Denbow et al., 1986), but results from work with cows in environmental chamber studies are mixed. Johnson et al. (1991) reported no effect of

temperature on plasma insulin concentrations in lactating cows, but Itoh et al. (1998) reported decreased insulin concentrations in non-lactating cows exposed to heat. Calves exposed to heat had decreased insulin concentrations within 0.5 h post-exposure and differences were maintained through 24 h of observation (Takahashi et al., 1986).

Amounts of supplement fed do not explain the differences in insulin concentrations because supplement provision was not different between housing treatments. One explanation may be related to sampling time. Cows kept in barns did not eat from approximately 0830 to 1800 h. Blood samples, collected at approximately 1700 h, would have been taken near the time of greatest nutrient depletion. These changes are corroborated by the fact that plasma insulin concentrations of cows fed silage in barn were similar to those of cows on pasture. In sheep infused with glucose, insulin concentrations increased to a greater degree during heat stress (Achmadi et al., 1993). Thus, the difference in plasma insulin concentrations between housing treatments may reflect both greater sensitivity to available nutrients in cows on pasture and a decrease in available nutrients for cows kept in the barn.

Effect of bST. Use of bST increased ($P < 0.001$) concentrations of plasma IGF-1 over controls nearly 70% (84.5 vs. 143 ng/ml of plasma). The bST treatment likely affected IGF-1 both directly and indirectly via increased concentrate provision. McGuire et al. (1992) reported that response to bST increased with increasing plane of nutrition. The IGF-1 concentrations in bST-treated cows were similar to those reported by Staples et al. (1988), but IGF-1 concentrations of untreated cows were about twice the concentration reported for controls in that study.

Insulin concentrations tended ($P < 0.10$) to increase due to bST at the second sampling date and as an average of all sampling dates. In a study involving increasing plane of nutrition and bST administration, plasma insulin concentrations increased with bST treatment for cows fed diets greater in energy density and crude protein concentration (diet by bST interaction) (McGuire et al., 1992).

Effect of supplemental silage. Feeding silage increased ($P < 0.05$) plasma IGF-1 concentrations at the second blood sampling date only. Concentrations of plasma IGF-1 might be expected to increase based on the results of McGuire et al. (1992) if total energy intake was increased in this group of cows.

Respiration Rates and Body Temperatures

Effect of housing. Cows kept on pasture during the daylight hours took nearly 30% more ($P < 0.001$) breaths/min than those housed in the barn (89 vs. 69 per min for barn and pasture cows, respectively). The RR of housed cows were somewhat greater than those reported for cows maintained in a thermoneutral environment, indicating some level of heat stress, but RR were somewhatlower than those typical of cows subjected to heat stress (Manalu et al., 1991; Zoa-Mboe et al., 1989). The RR of cows under shade on pasture were only 10% less than the RR of shaded cows in dirt lots reported by Zoa-Mboe et al. (1989), but the cows in this study had much lower levels of milk production. Further, a report of RR of 120 breaths/min for unshaded lactating cows (Zoa-Mboe et al., 1989) illustrates the degree of cow discomfort under Southeastern conditions without some method of reducing heat load.

By 0900 h, cows on pasture were hotter than cows kept in the barn (Figure 4.2). Temperatures of all cows continued to increase, peaking at approximately 1630 h, the

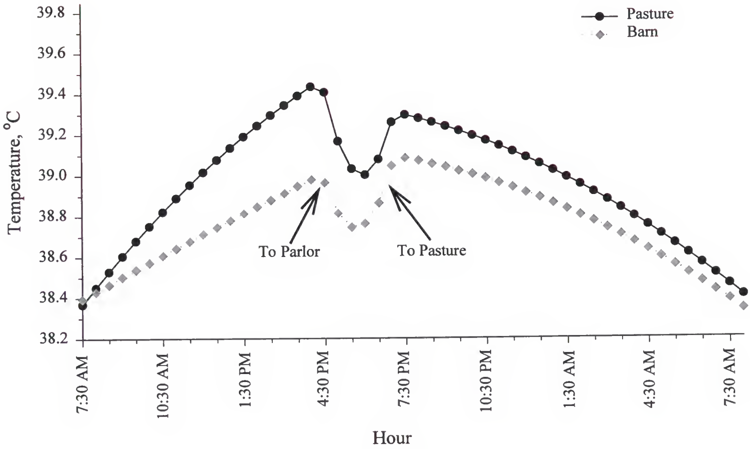

Figure 4.2. Effect of housing on body temperatures of cows measured over a 24-h period a averaged over bSt treatment regimes.

average time at which cows arrived at the parlor for milking. The temperature increases were greater for pasture cows, however, as indicated by the greater slope, and at 1630 h, temperatures were approximately 0.5 °C greater for cows coming from pasture (39.5 vs. 39.0 °C). Temperatures decreased immediately thereafter due to the cooling effect of the shower wash system. After milking, temperatures increased for both treatments as cows returned to pasture. This increase post p.m. milking was greater for barn cows, suggesting greater grazing activity than cows given access to pasture continually.

Effect of bST. Increased RR with bST treatment have been reported (Zoa-Mboe et al., 1989) but did not occur in this study, in agreement with Manalu et al. (1991). Cole and Hansen (1993) also reported no effect of bST on RR, but RR were much greater in their study and the authors suggested that the lack of difference due to treatment might have been due to second-phase panting which is associated with respiratory alkalosis (Bianca and Findlay, 1962).

Cows treated with bST had greater temperatures ($p< 0.05$) throughout the day, although temperatures were similar in the early morning (0730 to 0800) after a period of night cooling (Fig. 4.3). Cows not injected with bST increased body temperature at a slower rate from approximately 1100 h until 1630 h (Fig. 4.3). Treated cows had a nearly linear rate of temperature increase from the morning to evening milking. These results agree with the findings of others (Zoa-Mboe et al., 1989; West et al., 1990, 1991; Elvinger et al., 1992; Sullivan et al., 1992; Cole and Hansen, 1993) and contradicts early reports (Mohammed and Johnson, 1985; Manalu et al., 1991) that bST had no effect on rectal temperatures. Although the greater body temperatures associated with bST have been associated with increased milk production (West et al., 1990) work of Cole and

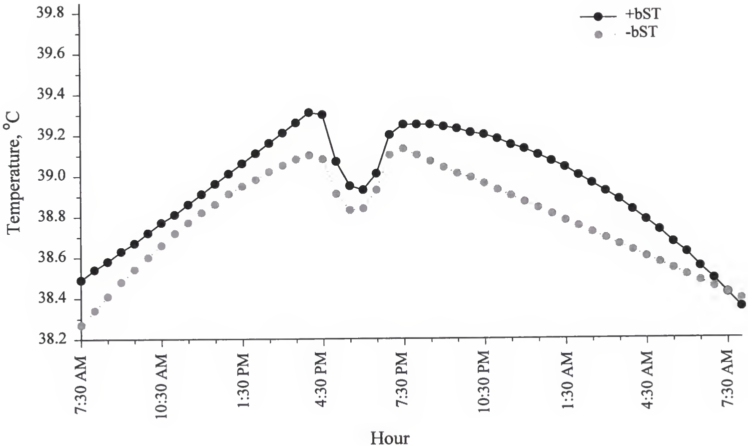

Figure 4.3. Effect of bST on body temperatures of cows measured over a 24-h period and averaged over daytime barn and daytime pasture housing regimes.

Hansen (1993) suggests that bST increases body temperatures of non-lactating cows as well.

Treatment with bST also affected body temperature patterns once cows returned to pasture, with treated cows maintaining increased body temperatures far longer than untreated cows. Though this temperature pattern for bST-treated cows appears to reflect a greater drive to graze, such a drive was not confirmed with the forage intake data. Therefore, cows receiving bST may have been more aggressive grazers (greater bite rate) upon initial return to pastures.

Effect of supplemental silage. Cows fed silage in the barn had a different temperature pattern than those not receiving silage (Figure 4.4). Body temperatures of cows on both treatments reached the same temperature within an hour of grazing (1900h), but temperatures of cows fed silage quickly dropped thereafter, suggesting that they spent less time grazing. Cows not fed silage but treated with bST had greater drive to graze than cows fed silage, and their temperatures were sustained until 0130 h, likely due to increased grazing activity.

From approximately 0930 to 1430 h, cows on pasture did not differ in temperature, regardless of bST treatment, whereas cows in the barn treated with bST had greater temperatures than non bST-treated cows (Fig. 4.5). Milk production was greater by bST-treated cows on pasture as well.

Conclusions

Use of exogenous bST increased milk production (1.5 kg/d; 9%) and 4% FCM production (1.9 kg/d; 12%) of cows managed in a pasture-based system regardless of type of heat abatement used. Economic benefit of its use will depend upon its cost vs. milk

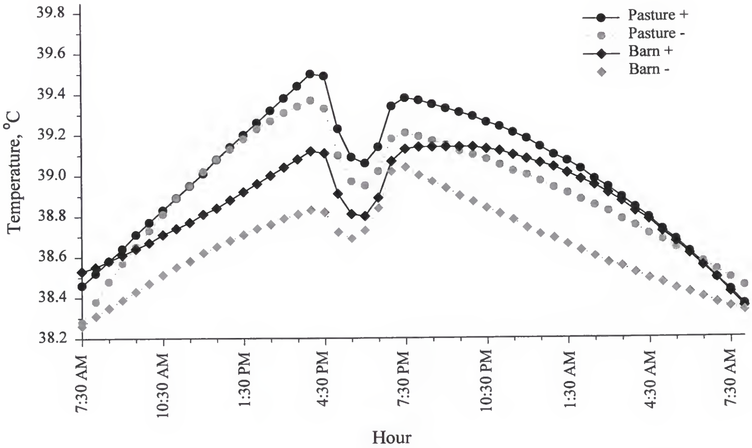

Figure 4.4. Regression equation estimates of body temperatures of cows measured over a 24-h period and showing interaction of bST (+ or -) and housing treatments.

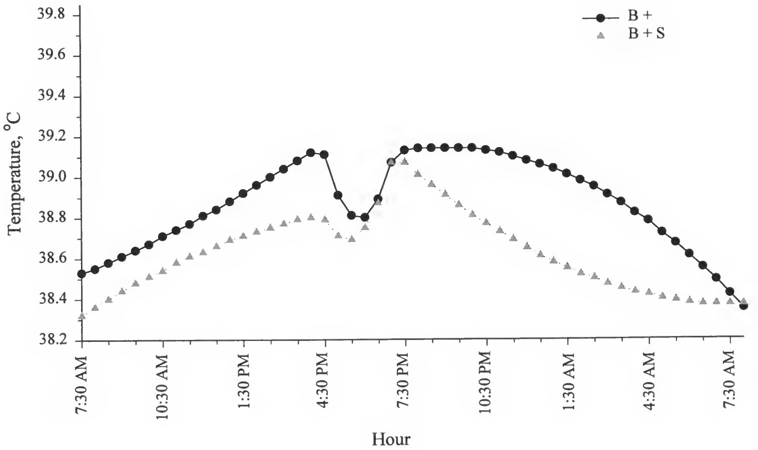

Figure 4.5. Effect of barn plus bST (B +) vs. barn plus bST plus silage (B + S) treatment on body temperatures of cows measured over a 24-h period.

price. Body temperatures increased in cows treated with bST likely due to increased metabolism associated with greater milk production and grazing activity. Milk fat and protein averaged 3.79 and 3.24% respectively and was unaffected by treatments. Intake of pasture was not affected by bST injections possibly because of greater intake of supplement. Greater intake of supplement also may have resulted in better management of body weight and greater concentration of plasma insulin of cows given bST.

Housing cows during the day effectively reduced heat stress as indicated by lower body temperatures and respiration rate. Production of 4%FCM increased (0.9 kg/d) in response to daytime housing. Though responses likely were not economical at this stage of lactation, some form of cooling other than shade alone may have benefit for cows in earlier stages of lactation. Daily OMI were not affected by housing system suggesting that cows housed in cooling barns during periods of peak heat stress and deprived of feed practiced compensatory intake when given access to pasture. Barn housing between 0800 and 1800 h did prevent body weight loss suggesting lower maintenance costs than cows without access to fans and sprinklers and required to walk greater distance for milking.

Provision of silage did not enhance milk production nor promote weight gain in this study. Cows reduced pasture OMI approximately 0.5 kg for each 1 kg of silage OMI, and the lack of production or gain response to silage indicates reductions in efficiency of nutrient utilization.

CHAPTER 5
FINAL SUMMARY AND CONCLUSIONS

In the USA, interest in the use of pasture-based forage systems for dairy production has increased in the past decade. Renewed interest in grazing for dairy cattle has been driven primarily by tightened economic conditions in which production costs increased while milk prices dropped. Southern producers wanting to know more about grazing have had little information upon which to make management decisions. Most information about dairy grazing in the USA comes from research conducted in temperate climates and is of limited relevance for producers in the South whose primary forage base is warm-season pasture. Thus, a series of experiments was conducted to quantify the responses of lactating Holstein cows to different grazing systems and management strategies.

The first two experiments tested the effects of grazing systems. Forages were bermudagrass (BG; *Cynodon spp.* cv. 'Tifton 85') and rhizoma peanut (RP; *Arachis glabrata* cv. 'Florigraze'), two relatively new forages available to producers. The forages were tested in combination with two stocking rates (SR) and two supplementation rates (SUP). The SR differed between forages to account for the different growth rates of the two species. The BG pastures were stocked at 5.0 or 7.5 cows/ha in 1995 and 7.5 and 10.0 cows/ha in 1996. The RP pastures were stocked at 2.5 and 5.0 cows/ha in 1995 and 5.0 and 7.5 cows/ha in 1996. Supplementation rates were 0.33 and 0.5 kg of supplement (as-fed basis)/kg of daily milk production.

Cows grazing RP pastures produced more milk than cows grazing BG (17.3 vs. 16.2 kg/d), but milk was of lower fat concentration. Because production per land area may be a more appropriate measure of profitability for dairies using grazing systems this measure also was calculated. Despite lower milk production per cow with BG, milk production per ha with BG pastures exceeded production per ha with RP pastures (118 vs. 87 kg of milk/ha per day) by nearly forty percent though this took more cows.

Across all treatments, cows lost an average of 6 kg/28-d period, with the majority of the loss occurring during the first period. Cows grazing RP were more heat stressed, having greater respiration rates, and they lost more BW (−10 vs. −5 kg/28-d period) than cows grazing BG. These measures are indicative of greater energy expenditure associated with greater milk production.

Tifton 85 and RP have both proven of acceptable quality for use in the diets of high-producing dairy cows kept in confinement housing (Staples et al., 1997; West et al., 1997), but dietary NDF and ADF concentration in these studies were much greater than recommended by NRC (1989) and may have limited intake, particularly for BG-based diets. Cows grazing RP pastures consumed 49% more forage OM than cows grazing BG pastures (11.3 vs. 7.6 kg of OM/d) and supplement intakes were greater when cows grazed RP because of their greater milk production.

In comparison with the NRC (1989) recommendation for feeding a reference cow of 500 kg and producing 20 kg of 4% FCM/d, DMI of the BG-based diets were limiting, and daily intakes of energy, CP, Ca and P were limiting when cows were fed the low SUP.

Comparison of OMI with NRC estimates of nutrient requirements suggests that OMI was over-predicted, particularly for RP pastures, but the data are subject to several sources of error. Overestimates of intake, underestimates of maintenance requirements, and overestimates of diet digestibility, (related to the prediction of associative effects) all may have limited the accuracy of prediction.

The estimates of OM and nutrient intakes for cows grazing RP suggest that forage quality was quite high, but the less than expected production responses obtained when cows grazed this forage suggest that nutrients of RP were poorly utilized. Increased maintenance costs, though likely greater due to increased heats of fermentation and milk synthesis, would be unlikely to account for production amounts less than those predicted. Thus, different feeding strategies with respect to supplements are likely necessary to optimally utilize RP's better nutritive characteristics.

Use of RP may be of benefit in mixed swards if a compatible, high quality grass is available. Poppi and McClennan (1995) reported that the benefit of legumes in pasture may be due primarily to their effect on intake rather than an improvement in forage nutritive value. The greater OMI of RP vs. that of BG suggests that the legume could be useful in stimulating intake if used as a companion with an appropriate graminaceous species.

Tifton 85 BG, despite large concentrations of fiber and moderate digestibility, proved to be a desirable forage for milk production on a land area basis. The high carrying capacity and the good response to supplement of cows grazing this forage are useful attributes for forages in grazing systems.

Herbage mass was never limiting for cows grazing BG, regardless of SR but HM appeared to be limiting when cows grazed RP at the high (7.5 cows/ha) SR. For BG, the tendencies of improved production at greater SR suggest that this forage requires greater management and utilization for optimal animal performance. Conversely, decreases in production at the greatest SR for cows grazing RP suggest that quantity, rather than quality, of available forage limited animal performance with this forage.

Cows grazing RP returned equal or greater income (milk income minus supplement cost) on a per cow per day basis than cows grazing BG ($4.13 vs. $3.85/cow per day) illustrating the higher digestibility and intake potential of RP. This advantage of RP over BG pastures was greatest when the amount of supplement fed was lowest ($4.27 vs. $3.80/cow per day, compared to $3.99 vs. $3.90/cow per day for the low and high SUP respectively). Feeding additional supplement was generated greater milk income only when BG was grazed. Milk income minus supplement costs were $0.11/cow per day greater for cows eating more supplement on BG but was $0.28/cow per day lower for cows eating more supplement on RP. These responses reflect the effects of substitution. One aspect of substitution not accounted for in this analysis is the potential for greater SR when feeding more supplement to cows grazing RP pastures.

The greater dollar return on a per cow basis for RP pastures is dwarfed by the greater income per unit land area capable with BG pastures. By these calculations, use of BG resulted in a 40% greater dollar return/ha. Average income/ha for BG was $28.95 vs. $20.65 for cows grazing RP.

Supplementation rate affected all milk production and milk component responses except SCC. Cows receiving the greater SUP produced more milk of lesser fat

concentration. Supplement likely increased growth of ruminal microbes and this would explain the increased milk protein percentage with the greater SUP.

Feeding sizeable quantities of supplemental energy feeds can obscure the effects of forage quality on animal performance (Waldo, 1986). Further, several researchers (Blaxter and Wilson, 1963; Golding et al., 1976b; Arriaga-Jordan and Holmes, 1986) have reported greater substitution with better quality forages. That appeared to be a particular limitation with RP. With each additional kg of supplement fed above the low SUP, cows produced an additional 0.87 kg of milk/d if grazing BG vs. an additional 0.43 kg of milk/d if grazing RP.

The response to supplement on a land-area basis was greater when cows grazed BG than RP (132 and 110 kg of milk/ha per day at high and low SUP for BG vs. 90 and 83 kg of milk/ha per day at high and low SUP for RP). Both the lesser substitution of forage with supplement by cows on BG and the greater carrying capacity of BG pastures affected this response.

Surprisingly, SUP had no effect on changes in BW, nor were SUP by treatment interactions detected. However, BW losses were numerically greater with the greater SUP, in agreement with the observation that treatments supporting greater milk production promoted BW loss. Feeding additional supplement caused a 10% increase in RR (99 vs. 90 breaths/min).

Although total OMI increased approximately 2 kg/d with additional supplement, forage OMI was reduced approximately 1kg/d, and cows grazing RP pastures experienced a greater decrease in forage consumption when fed more supplement compared to those grazing BG pastures. The substitution of forage OM by supplement

OM (kg/kg) was 0.51 for RP and 0.18 for BG. Cows grazing BG pastures and provided greater amounts of supplement increased total OMI by 22 % vs. a 10 % increase in total OMI with additional supplement for cows grazing RP.

The limited improvement in production with RP over that with BG suggests that use of adapted leguminous forages has little merit in these systems (Rouquette et al., 1993). This likely will remain true as long as inexpensive by-product energy feeds are available. However, production limits due to forage substitution may be offset by the ability to increase SR, and to a greater degree with RP than BG.

The calculated nutritional deficiency for cows grazing BG and fed the low SUP indicates that large amounts of supplement must be fed or the supplement nutrient concentrations must be adjusted to ensure adequate nutrient intake when BG is managed as in these experiments. Oppositely, supplement intakes caused RP-based diets to contain excessive CP, likely increasing maintenance costs due to the need for increased N excretion. With RP, only S intake appeared marginal regardless of SUP.

Nutrient intake estimates with both forages highlights the need for feeding suitable amounts of supplement with appropriate nutrient concentrations.

One limitation of the study presented was the use of the same supplement for animals grazing both forage types. Though this prevented the confounding of forage effects with supplement effects, the response to supplement likely would be improved by more appropriately balancing the supply of nutrients available to the cow. Although this may not affect production, a more economical supplement could be offered (Hoffman et al., 1993).

Stocking rate did not influence milk production, but cows grazing at lower SR tended to produce milk with greater concentrations of protein which may reflect opportunity to select plant parts of greater nutritive value. Likewise, in 1996 MUN was lower when cows were stocked at the lower rate suggesting more efficient use of dietary CP for milk protein.

On a land area basis, the effect of SR on milk production was greater than the effect of feeding additional supplement. Increasing SUP from 0.33 kg of supplement:1 kg of daily milk to 0.5 kg of supplement:1 kg of daily milk increased ($P < 0.001$) milk production 14% on a land area basis (97 vs. 111 kg of milk/ha per d), but increasing SR resulted in a 51% increase ($P < 0.001$) in milk production per land area (83 vs. 125 kg of milk/ha per d).

Cows assigned to the greater SR lost 7 to 8 kg more per 28-d period than cows assigned to the lower SR across years and forages with one exception. In 1996, cows grazing BG lost 7 kg less BW when grazing at the greater vs. lesser SR

Increasing SR resulted in reduced forage OMI , but cows stocked at the greater rate were fed slightly more supplement because of greater milk production. Thus, total OMI and OMIPBW were not different due to SR (15.3 and 15.9 kg of OM/d and 3.08 and 3.16% of BW/d).

In a third study, the effect of additional management strategies on milk production was investigated. Cows were housed in barns (with fans and sprinklers) or on pastures (with shade cloth only) between AM and PM milkings. After PM milking all cows returned to BG pastures. Within housing treatments, cows did or did not receive bST

injection, and a fifth treatment tested the effect of feeding supplemental silage to cows treated with bST and housed in barns.

Keeping cows in the barn limited their time spent grazing, but despite the reduced grazing time, forage intake was not compromised by barn housing. Average forage OMI of BG, excluding cows on the silage treatment, was 9.2 kg/d, or 1.58% of BW. Because forage OMI was unaffected by grazing time, housed cows must have grazed with greater harvesting efficiency (defined as intake over time (Barton et al., 1992; Krysl and Hess, 1993). This might have occurred as a result of an increased bite rate due to temporary deprivation from pastures as has been reported by Greenwood and Demment (1988).

Supplement and total OMI were unaffected by housing treatment. Average supplement and total OMI were 7.5 and 16.7 kg/d. Daytime housing with fans and sprinklers increased ($P < 0.11$) milk production by 5% for housed cows (17.8 vs. 17.0 kg/cow per d, respectively).

That differences between housing regimes were not greater in this study is surprising given the presumed greater energy expenditure of cows kept on pasture. The greater milk production from housed cows despite having similar OMI to those of pastured cows indicates a greater efficiency of nutrient utilization for housed cows. It is highly likely that housed cows expended less energy for maintenance because they were required to walk less and experienced less heat stress.

Housing cows during the day did promote weight gain. Cows kept on pasture lost approximately 11 kg of BW/24-d period vs. an increase of approximately 6 kg of BW/24-d period for housed cows. These differences in BW changes further highlight the lower maintenance costs for housed cows due to reductions in activity and heat stress.

Housing had no effect on IGF-1 at any sampling date. Greater insulin concentrations were detected for cows kept on pasture continually

Cows kept on pasture during the daylight hours took nearly 30% more breaths/min than those housed in the barn (89 vs. 69 per min for barn and pasture cows, respectively). By 0900 h, cows on pasture were hotter than cows kept in the barn. Temperatures of all cows peaked at approximately 1630 h when cows were washed for the evening milking. Body temperatures decreased immediately thereafter due to the cooling effect of the shower wash system. After milking, temperatures increased for both housing treatments as cows returned to pasture, but the increase post p.m. milking was greater for barn cows, suggesting greater grazing activity of the cows denied access to pasture during the day.

Responses to cooling with fans and misters may be greater with more modern cooling equipment (fans were an older, box-type with slower wind speed), but such equipment may be more typical of systems put in place by low-input operators. Regardless, the effect of cooling likely would be greater for cows in earlier stages of lactation when milk production and heats of metabolism would be greater. Economic feasibility of constructing such facilities for a pasture-based startup operation seems unlikely but must consider the life of the system. Use of such pre-existing facilities might have financial merit.

Research with other types of cooling may warrant exploration. Some producers have taken advantage of the shallow subsurface waters common to the state by digging cooling ponds. In these more limited input systems, use of trees as a resource for both cooling and harvest may have financial benefit.

Treatment with bST encouraged increased grazing activity (6.3 vs. 5.6 h of grazing/d), but forage OMI was unaffected by bST treatment. Given the conditions imposed, cows treated with bST would not be expected to increase intake of forage OM since supplement provided was increased with increasing milk production. If bST-treated cows consumed only pasture, forage intakes likely would have increased given adequate amounts of available herbage.

Cows injected with bST increased milk production approximately 9% (18.1 vs. 16.6 kg/d) and thus were fed an average of 8.0 kg of supplement OMI/d vs. 7.0 kg/d for untreated cows. Although within the range of reported production increases in response to bST, greater responses to bST might have been expected given the relatively low amount of pretreatment milk production.

On average, and despite increased milk production, cows treated with bST gained small amounts of BW (2.5 kg/24-d period), but cows not given bST lost about 7 kg of BW/24 d period. The BW gain response was likely a result of the increased supplement provided to bST-treated cows because they produced more milk.

Use of bST increased concentrations of plasma IGF-1 over controls nearly 70% (143.vs. 84.5 pg/ml of plasma). The bST treatment likely affected IGF-1 both directly and indirectly via increased concentrate provision. Averaged over all sampling dates, insulin concentrations tended to increase due to bST treatment. As with IGF-1, bST likely affected insulin concentrations directly and indirectly via increased supplementation.

Increased RR with bST treatment has been reported but did not occur in this study. However, cows treated with bST had greater temperatures throughout the day.

The increase in body temperature is in agreement with several other studies and contradicts popular press and technical reports of Monsanto which suggest that cows are capable of dissipating additional heat via greater RR and sweating.

Cows not injected with bST increased body temperature at a slower rate from approximately 1100 h until 1630 h. Treatment with bST also affected body temperature patterns once cows returned to pasture, with treated cows maintaining increased body temperatures far longer than untreated cows. Though this temperature pattern for bST-treated cows appears to reflect a greater drive to graze. Also cows receiving bST may have been more aggressive grazers (greater bite rate) upon initial return to pastures.

Feeding silage curtailed grazing time by more than 25% (5.6 vs. 4.0 h of grazing/d). The decreased grazing time resulted in decreased BG OMI of about 18% (from 9.0 to 7.4 kg/d, respectively), but total forage OMI was increased approximately 17% with supplemental silage (from 9.0 to 10.5 kg of forage OMI/d).

As feeding silage did not affect milk production, supplement OMI was not different between the plus or minus silage treatments. Cows fed silage consumed more total OMI per day by nearly 8%. Whereas the equation of Moore et al. (1999) was used to adjust forage digestibility due to associative effects of supplement feeding and thus forage intake estimates, no additional adjustments to forage digestibility were made for cows consuming corn silage. If feeding corn silage resulted in a greater depression of pasture digestibility, OMI was over-predicted.

Feeding supplemental silage in the barn had no effect on milk production, 4% FCM production, nor milk fat and protein concentrations or quantities. Barn cows not receiving silage also tended to gain more than those fed additional roughage in the barn.

Because OMI was increased for cows fed silage with no change in milk production, partitioning of nutrients to BW gain might be expected. This seeming discrepancy could be a consequence of the postulated difference in gut fill between the two treatments and if so indicates that condition score measurements were based upon more than changes in fat depot size. Because neither milk production nor weight gain increased with the increased OMI, efficiency of nutrient utilization may have decreased with supplemental corn silage, or intake of metabolizable energy may not have been increased.

Cows fed silage in the barn had a different temperature pattern than those not receiving silage. Body temperatures of cows on both treatments reached the same temperature within an hour of grazing (1900h), but temperatures of cows fed silage quickly dropped thereafter, suggesting that they spent less time grazing. Cows not fed silage but treated with bST had greater drive to graze than cows fed silage, and their temperatures were sustained until 0130 h, likely due to increased grazing activity.

Estimates of nutrient intake based on NRC recommendations suggest that nutrient intake did not prevent cows on this trial from producing 20 kg of 4% fat corrected milk/d. This suggests that either maintenance costs were greater than NRC (1989) estimates, or nutrient intake or utilization, particularly of energy, was overestimated.

Pasture-based production systems may be viable for dairies in the Southeast, but they must overcome several obstacles to profitability. Low forage quality, environmental stresses, greater maintenance costs for grazing cows, and animal adaptation may all limit the productivity of these systems.

Cows grazing pasture typically have lower peak milk production and are less persistent (Hoffman et al., 1993). The effects of hot environments likely further

compound these problems due to the fact that animals decrease intake during heat stress to help maintain homeothermy. Further, the strains of heat and humidity place additional maintenance demands on the cow.

Feeding supplemental silage to housed cows was ineffectual. The lack of positive response, teamed with the greater forage intakes suggest that feeding silage resulted in reductions of nutrient utilization efficiency.

Use of management tools such as bST may have merit for periods of the grazing season when cows are in good condition, but the limited response to bST in this study suggests that economic returns may be minimal during the summer. Response to bST typically is greater for cows of lower milk production, and the limited response to treatment for the mid- to late-lactation cows in this study suggests that bST may be ineffectual for cows nearer peak production.

Other considerations for pasture-based dairies in the Southeast would include alternative forage crops which could fit the difficult-to-fill production windows of late fall and early spring. These seasons are particularly difficult in regions such as North Central Florida, where transition periods occurring between the growth of warm and cool season forages limits available forage.

Breed of cattle likely is another area rich for exploration. Holsteins may not be best suited to pasture dairying in the Southeast, and use of breeds more tolerant of heat stress may be of advantage for the systems. Currently some graziers are attempting to improve the productivity of their herds by cross breeding Jersey and Holstein cows to improve heat tolerance, optimize milk production and reproductive success.

Another production model, which has not been explored in modern Florida, is use of the dual purpose cow. Such systems are commonplace in Latin America where fluctuations in milk and meat prices allow producers to take advantage of these combined traits depending upon the market. Some pasture-based producers are breeding cattle that fit this model, but these cattle and systems are unlikely to garner wide interest in Florida due to its status as a milk-deficit state. Indeed, the premium placed on milk production in the state, and the as-yet more limited production with grazing systems suggests that at this time, grazing systems may be more effective as a route of entry into dairy production for producers with limited equity.

APPENDIX 1
SAS PROGRAM OF POND ET AL. (1987) FOR THE ESTIMATION OF FECAL OUTPUT

```
======================SAS PROGRAM======================

DATA GRAZE1; INFILE GRAZE;

INPUT ANIMAL TIME CR;
Y = CR;
PROC SORT; BY ANIMAL;
PROC NLIN INTER (sic) = 50 CONVERGENCE = .00001 METHOD =
MARQUARDT; BY ANIMAL;
PARMS K0 = 100 L1 = .05 TAU = 10;
BOUNDS K0>0, L1>0, TAU>0;
T = TIME – TAU;
If T<0 THEN GO TO ALPHA;
E1 = EXP (-L1 *T);
ONE = T*(L1**2)*E1;
MODEL Y = ((K0*L1*T)*(EXP(-L1*T)))/.59635;
   DER. K0 = ONE;
   DER. L1 = T*L1*K0*E1*(2-L1*T);
   DER. TAU = K0*(L1**2)*E1*(L1*T-1.0);
GO TO BETA;
ALPHA;
   MODEL Y = 0;
      DER. K0 = 0;
      DER. L1 = 0;
BETA: ;
OUTPUT OUT = POINTSI PREDICTED = YHAT RESIDUAL = RESID;
DATA OK; MERGE POINTSI GRAZE1;
PROC SORT; BY ANIMAL;
PROC PLOT; BY ANIMAL;
   PLOT YHAT * TIME = '*' Y*TIME = '+' /OVERLAY;
   LABEL TIME = TIME AFTER DOSE, HOURS;
```

APPENDIX 2
SAS PROGRAM TO ADJUST FORAGE INTAKE UNTIL FECAL OUTPUT OBSERVED AND FECAL OUTPUT PREDICTED DIFFER BY LESS THAN ONE-HUNDREDTH OF A KILOGRAM PER DAY

Program terms:

FRGDIG	= forage digestibility
IVOMD	= *in vitro* organic matter digestibility
FRGINTAK	= forage intake
TOTINTAK	= total intake (initially predicted from parameters derived from fecal excretion curves)
SUPINTAK	= supplement intake (assumed constant)
TOTDIG	= sum of digestible forage and digestible supplement intakes divided by total intake
FRGDIG	= forage digestibility (determined from laboratory analysis)
SUPDIG	= supplement digestibility (assumed constant)
FOP	= fecal output predicted
FOO	= fecal output observed
DIFF	= difference of observed and predicted fecal output

OMD is calculated in each iteration - call that the "expected" OMD.
Convert "expected" to "adjusted" with the following formula:
Adjusted OMD = 59.71 – (0.8948 * expected OMD) + (0.01399 * (expected OMD)^2)/100

```
=====================SAS PROGRAM=====================
DATA  ;

INPUT COW PAR TRT PER PAST YR OMI FOO IVOMD SUPINTAK SUPDIG;
FRGDIG = IVOMD;
DO FRGINTAK =1 TO 40 BY .05 UNTIL (DIFF < .01);
TOTINTAK = FRGINTAK + SUPINTAK;

EXPDIG = (FRGINTAK*FRGDIG + SUPINTAK*SUPDIG)/TOTINTAK*100;
ADJDIG = (59.71 - 0.8948*EXPDIG + 0.01399*EXPDIG**2)/100;
FOP = TOTINTAK*(1-ADJDIG);
DIFF = FOO-FOP;
END;
CARDS;
;
PROC PRINT;
RUN;
```

APPENDIX 3
WEEKLY WEATHER DATA FOR 1995, 1996 AND 1997 GRAZING TRIALS

		Temperature, °C		
Date	Rainfall, mm	Minimum	Maximum	Mean
1995				
July 10-16	26.3	21.9	34.7	27.5
July 17-23	92.8	20.6	34.7	27.5
July 24-30	38.9	20.0	35.0	26.9
July 31-Aug. 6	52.8	21.1	34.2	27.2
Aug. 7-13	43.4	20.6	34.2	27.3
Aug. 14-20	38.7	20.3	34.2	27.3
Aug. 21-27	71.6	21.1	32.2	26.4
Aug. 28-Sept. 3	8.8	21.7	33.3	27.0
Sept. 4-10	4.3	19.4	31.9	24.9
Sept. 11-17	45.3	20.0	33.3	26.7
Sept. 18-24	9.8	17.5	33.6	26.3
Sept. 25-Oct.1	9.0	18.1	30.8	25.4
Oct. 2-8	81.0	21.4	31.7	26.5
Oct. 9-10	7.5	22.2	30.8	26.3
1996				
July 9-15	30.2	22.8	34.2	27.0
July 16-22	20.3	20.6	34.2	27.3
July 23-29	0.0	18.9	36.4	27.7
July 30-Aug. 5	65.5	19.4	35.3	26.8
Aug. 6-12	34.9	19.2	33.9	26.2
Aug. 13-19	31.2	19.4	32.5	25.5
Aug. 20-26	7.0	18.9	33.1	25.5
Aug. 27-Sept. 2	75.7	15.6	31.9	25.1
Sept. 3-9	1.5	18.3	33.3	26.1
Sept. 10-16	15.0	16.4	33.1	25.3
Sept. 17-23	14.2	13.1	31.4	24.5
Sept. 24-30	0.5	13.6	32.2	24.3
Oct. 1-2	23.9	21.4	31.1	26.3
1997				
July 28-Aug. 3	103.9	20.3	32.5	26.4
Aug. 4-10	17.0	16.9	33.3	27.0
Aug. 11-17	21.3	21.7	34.4	27.9
Aug. 18-24	1.3	17.8	35.0	27.5
Aug. 25-31	51.3	15.3	34.4	25.4
Sept. 1-7	8.9	15.8	33.3	25.9
Sept. 8-14	0.0	15.0	33.9	25.3
Sept. 15-21	0.0	16.9	34.2	26.5
Sept. 22-28	56.1	20.0	35.0	26.3
Sept. 29 - Oct. 5	3.3	15.0	31.7	24.2
Oct. 6 - 10	5.1	15.6	31.4	24.1

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BIOGRAPHICAL SKETCH

John Herschel Fike, son of Herschel Ringgold and Shirley Hayden Fike, was born and raised in Franklin County, Virginia. He holds a B.S. in science education from Wake Forest University, an M.S. in forage agronomy from Virginia Polytechnic Institute and State University, and with successful defense of this dissertation holds a Ph.D. with specialization in dairy cattle nutrition from the University of Florida.

After graduating from Wake Forest University, John spent more than a year traveling and working in Japan, New Zealand, Australia, and several countries in Southeast Asia. His jobs included painting houses and milking cows in New Zealand, dagging sheep in Australia, and teaching English to Japanese businessmen.

While completing his Ph.D., John married Wonae (Bong) Fike of South Korea and started a family. He and Wonae are the proud parents of Jonah Paul Bong Fike.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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